CERES Instrument Status
Flight Models 1-6 (FM1-FM6)

Mohan Shankar

CERES Instrument Working Group

CERES Fall Science Team Meeting,
Lawrence Berkeley National Lab,
Berkeley, CA
October 29, 2019

Instrument Working Group

Chair: Kory Priestley

Instrument Operations

- B. Mike Tafazoli -
Janet Daniels
Christopher Brown
John Butler
Alexander Thickstun
Adam Horn
Carol Kelly
William Edmonds

Data Management

- Denise Cooper -
- Dale Walikainen -
A. Thomas Grepiotis
Mark Timcoe
Dianne Snyder

Science

-Susan Thomas–
Phillip Hess
Hyung Lee
Nathaniel Smith
Nitchie Smith
Z. Peter Szewczyk
Robert Wilson

CERES Instrument Operations

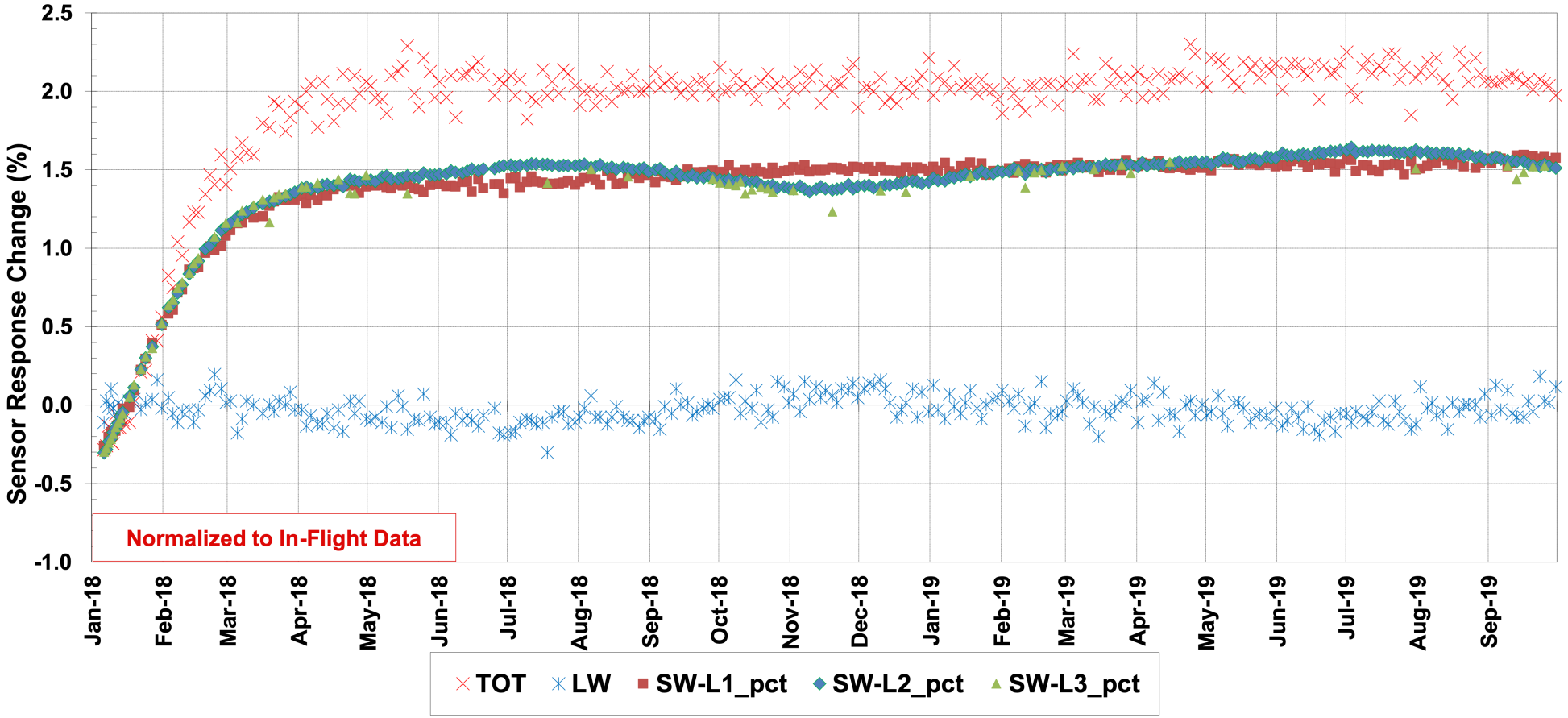
- **Flight Models (FM) 1-4, FM6 are in nominal mode of operation- Crosstrack.**
- **FM5 is operating in Biaxial mode since Oct 1, 2019.**
- **Support of the MOSAiC Expedition:**
  - CERES FM2 targeting the location of the Polarstern.
  - Trial runs being planned during the next few months.
- **Inter-comparison Operations during summer 2019**
  - Terra/FM1 – S-NPP/FM5: May 1 – Jul 31, 2019
  - Terra/FM1 – NOAA-20/FM6: May 1 – Jul 31, 2019
  - Terra/FM1 – Aqua/FM3: Jun 1 – 30, 2019

  Overpass region around 70^0 N
  - Terra/FM2 – GERB: Jun 1 – 30, 2019 → 60^0 N –0^0 (Equator)

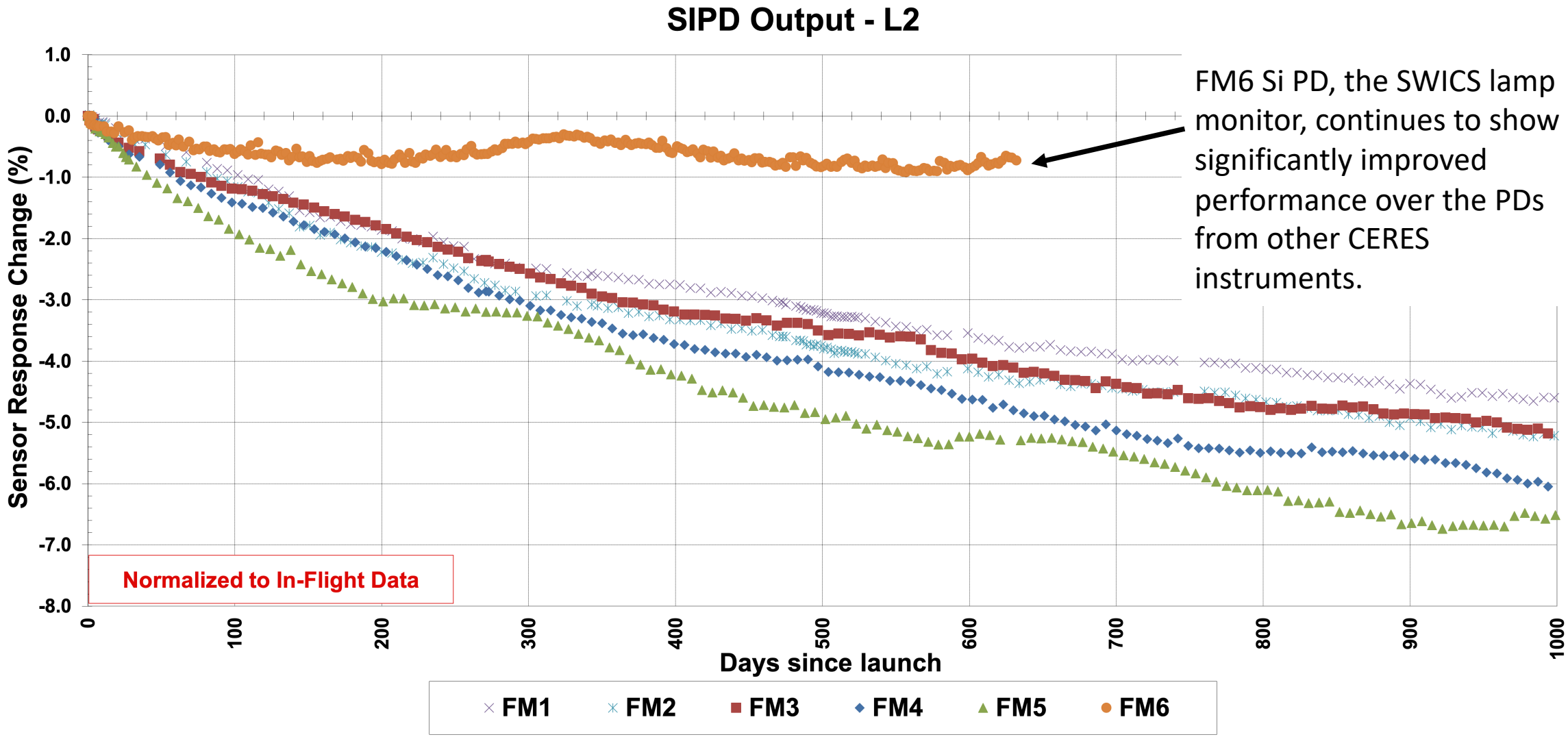
NOAA-20/FM6 Instrument Status

FM6 Internal Calibration

- **For SW and TOT channels, the responses to the on-board sources (SWICS lamp and Blackbodies) continue to be stable after the initial rise of ~1.5% (SW) and ~2% (TOT).**
- **LW Channel (calibrated using blackbody) continues to show very little variation.**



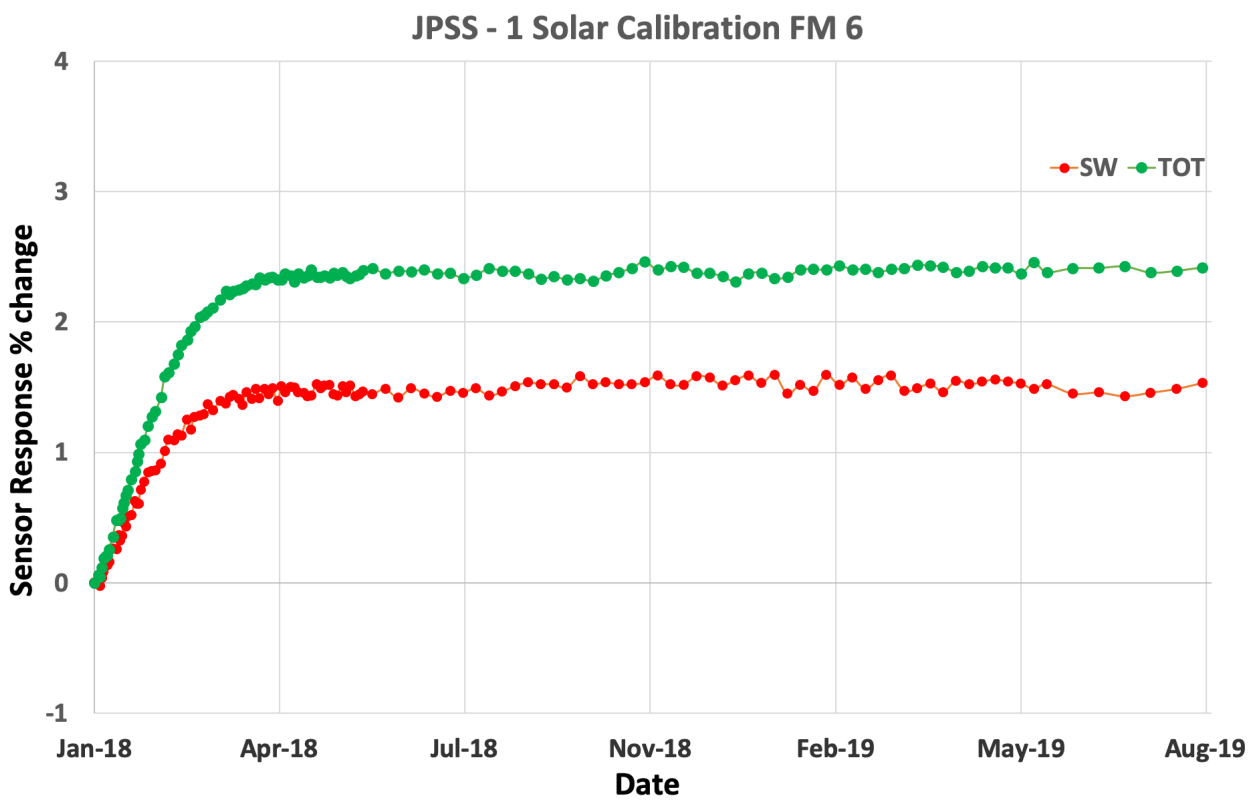
FM6 SWICS Silicon Photodiode

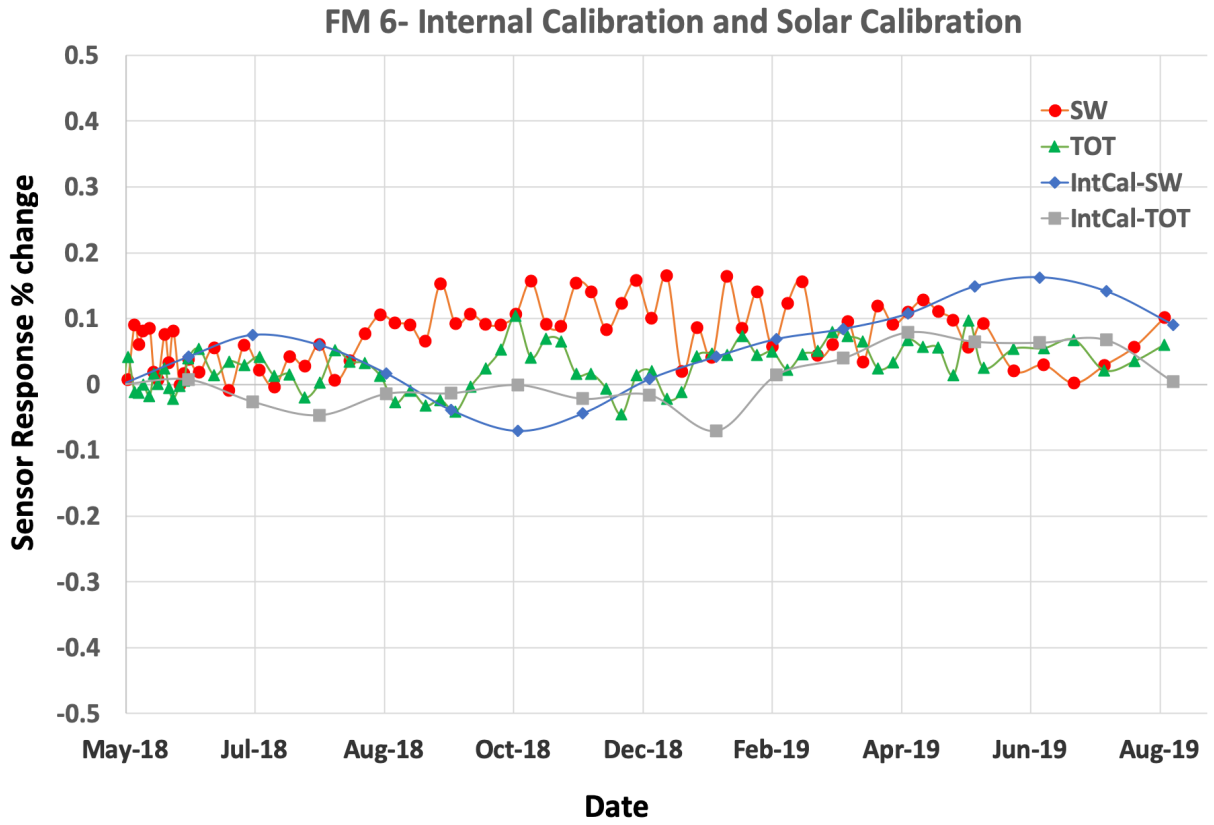


FM6 Si PD, the SWICS lamp monitor, continues to show significantly improved performance over the PDs from other CERES instruments.

FM6 Solar Calibration

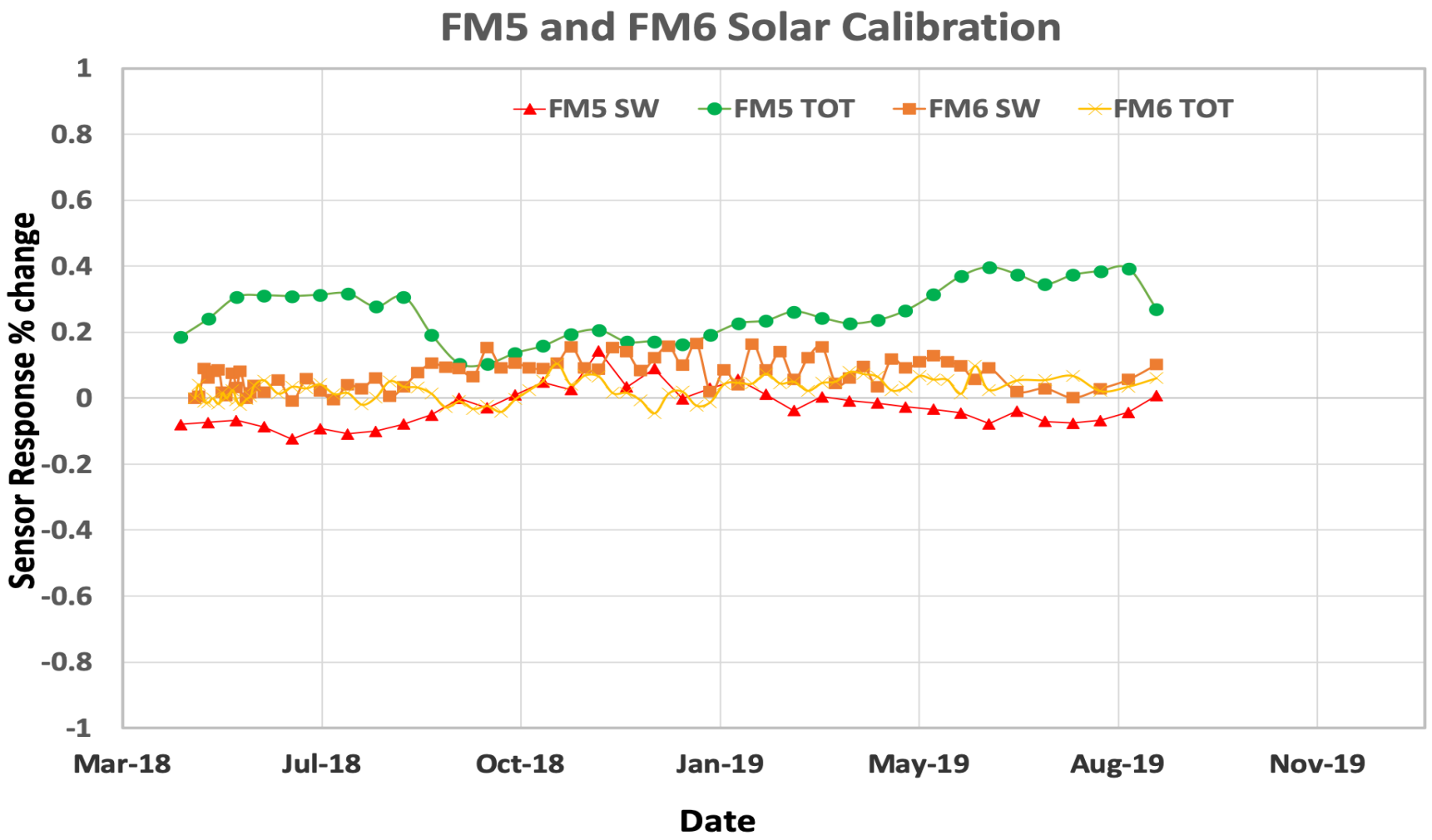
- **Solar Calibration results for SW and TOT channels show similar performance to the response to on-board calibration sources.**
- **After the initial rise of ~1.5% for SW, and ~2.5% for TOT, the response is very stable.**





FM6 vs. FM5 Solar Calibration

In comparison with FM5 solar calibration trends, the results from FM6 show the MAMs are stable.



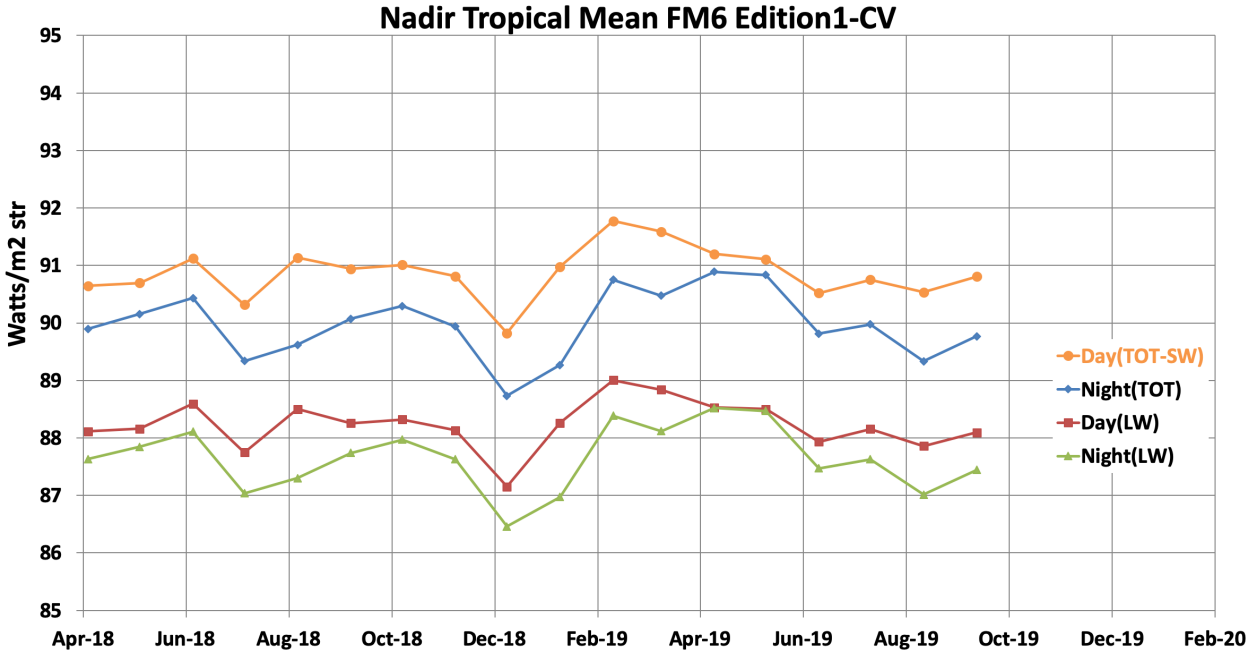
Validation – Tropical Mean

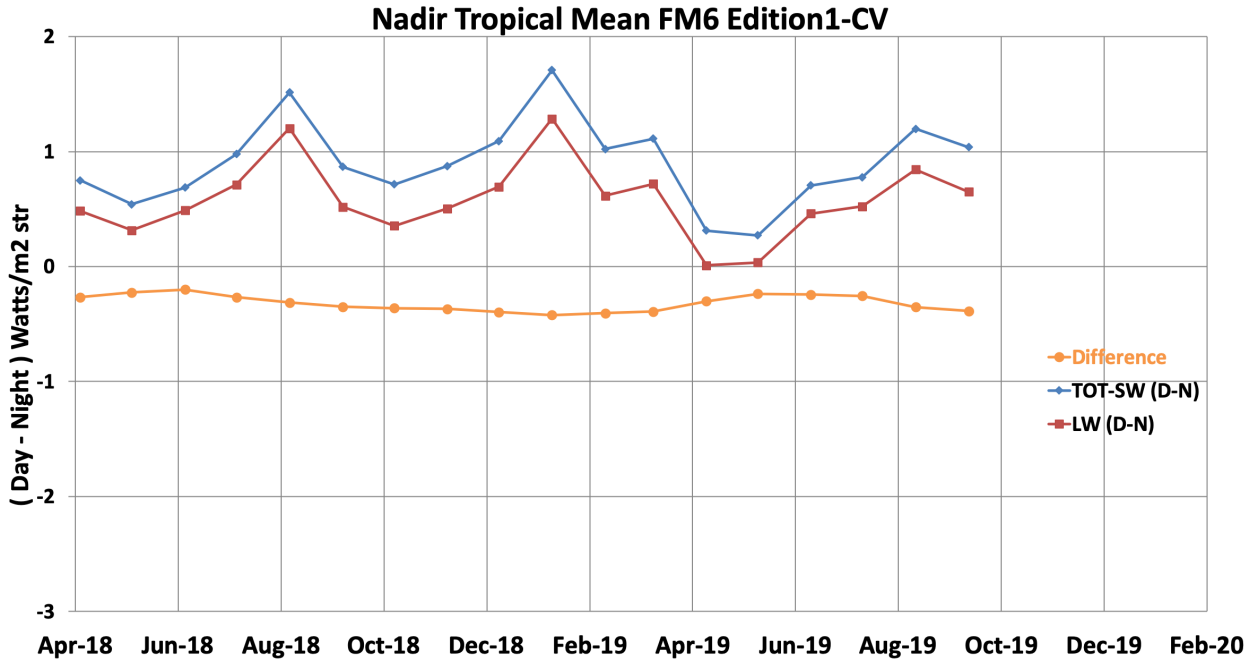
- Average of the Nadir radiances over Tropical ocean (20^0N-20^0S) scenes under All-sky conditions.
- TM Day-Night Difference (DN) is calculated:
  - TOT and SW sensors

    $DN = TM_D(TOT\text{-}SW) - TM_N(TOT)$
  - LW sensor

    $DN = TM_D(LW) - TM_N(LW)$
- Difference in the two DN values point to an anomaly in the shortwave regions of the sensors.

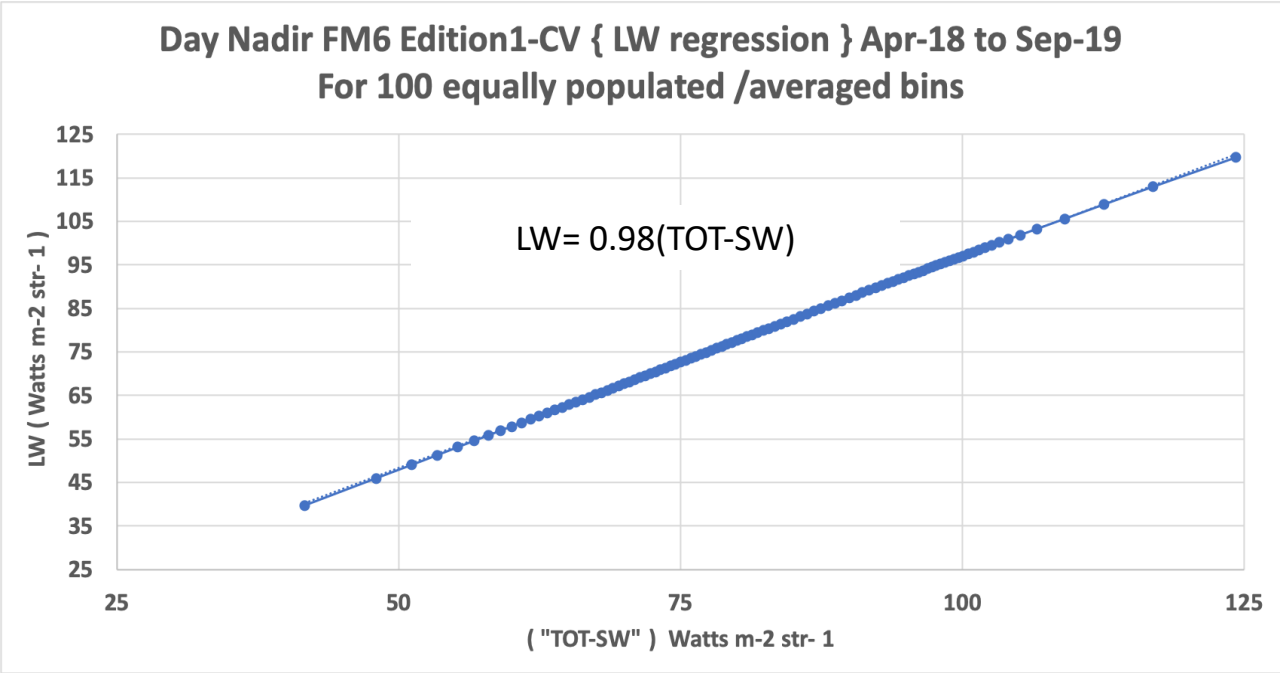
Validation- FM6 Tropical mean



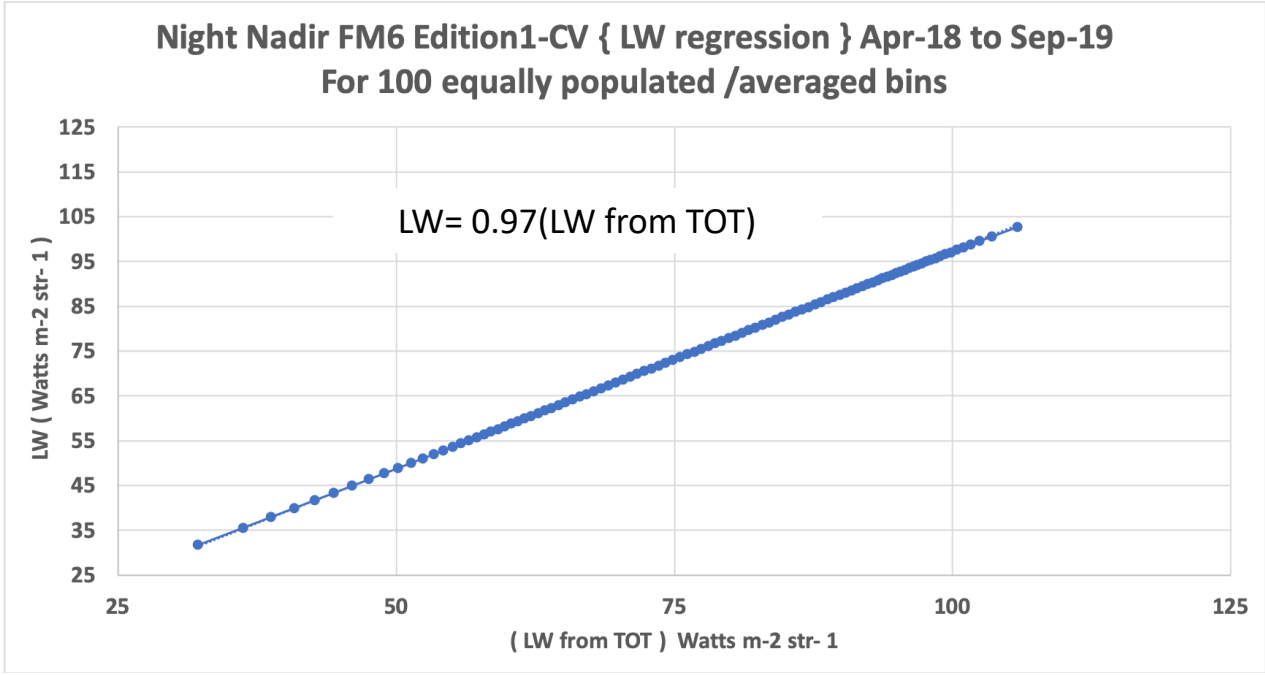


FM6 3-channel Consistency check- LW Day and Night

Day
TOT- SW vs. LW sensor



Night
LW from TOT vs. LW sensor



FM6 Edition-1 path forward

- **Update the sensor gains.**
  - Start from May 2018.
- **Perform radiometric scaling to Aqua/FM3 at BOM**
  - We've used SSFs earlier and we will need to evaluate the ability to use ES-8s in case SSFs are not available.
- **Look for long term trends in validation studies to point to spectral changes (none observed so far)**:
  - Tropical Mean
  - 3-channel Consistency checks: TOT-LW vs. SW and LW + SW vs. TOT for various scenes.

S-NPP/FM5 Instrument Status

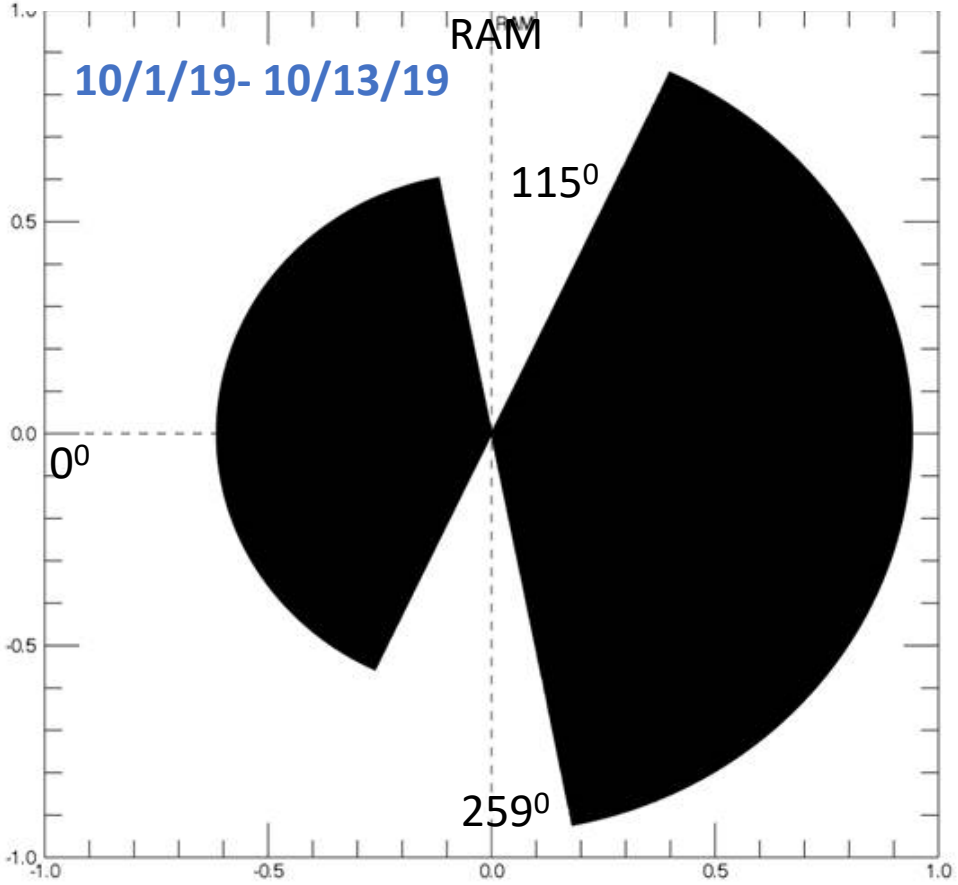
FM5 Biaxial mode test run

- **FM5 was operated in biaxial mode between Aug 18 – Sept 1, 2019 as a test run.**
- **Total channel resets occurred due to obstruction by the HRD antenna that appears in the telescope FOV during space view in azimuth angle range 101-112 degrees.**
  - Space look corruption occurs for all three channels, but the TOT channel signal was large enough to cause resets.
- **The azimuth angle range has now been revised to start at 115 degrees.**

FM5- Biaxial operation

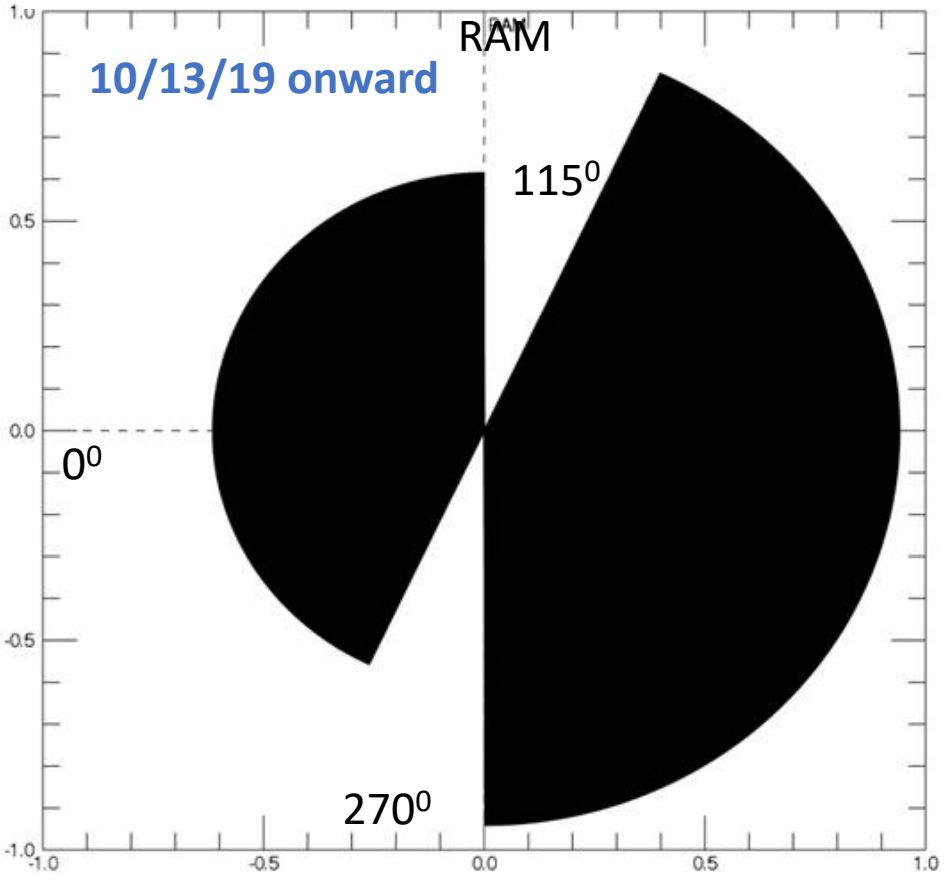
FM5 is operating in Biaxial mode since 10/1/2019.

Low solar Beta angle, Az range 115 - 259 deg



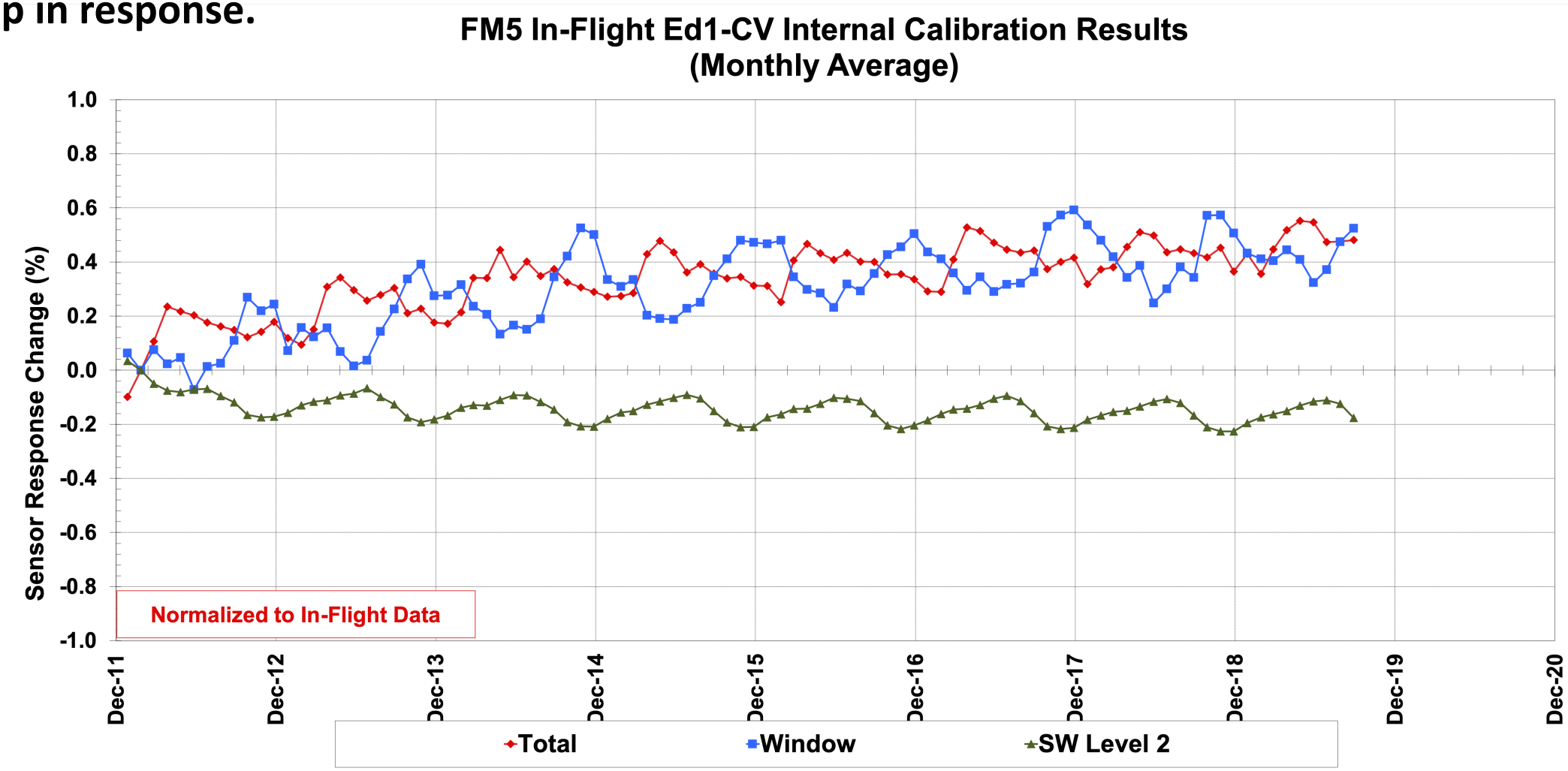
El Range:
Short scan

High solar Beta angle, Az range 115 - 270 deg



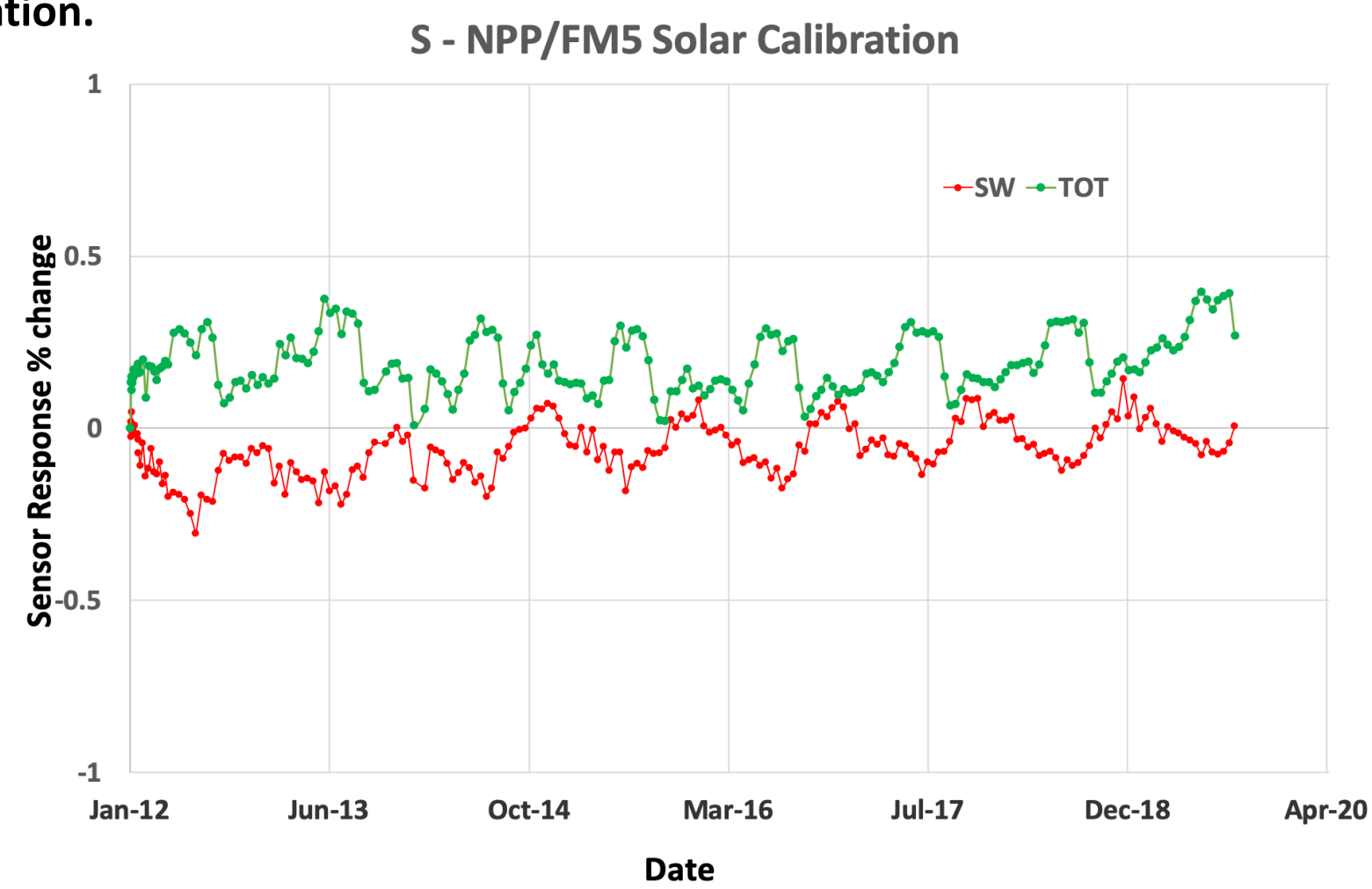
FM5 Internal Calibration

FM5 TOT and WN sensors show a ~0.5% rise, while the SW channel settled after initial ~0.2% drop in response.



FM5 Solar Calibration

- **FM5 Solar calibration results show the MAMs are very stable. TOT response is steady, while the SW response shows a slight upward trend.**
- **Currently the team is performing analysis to compare internal calibration and solar calibration.**



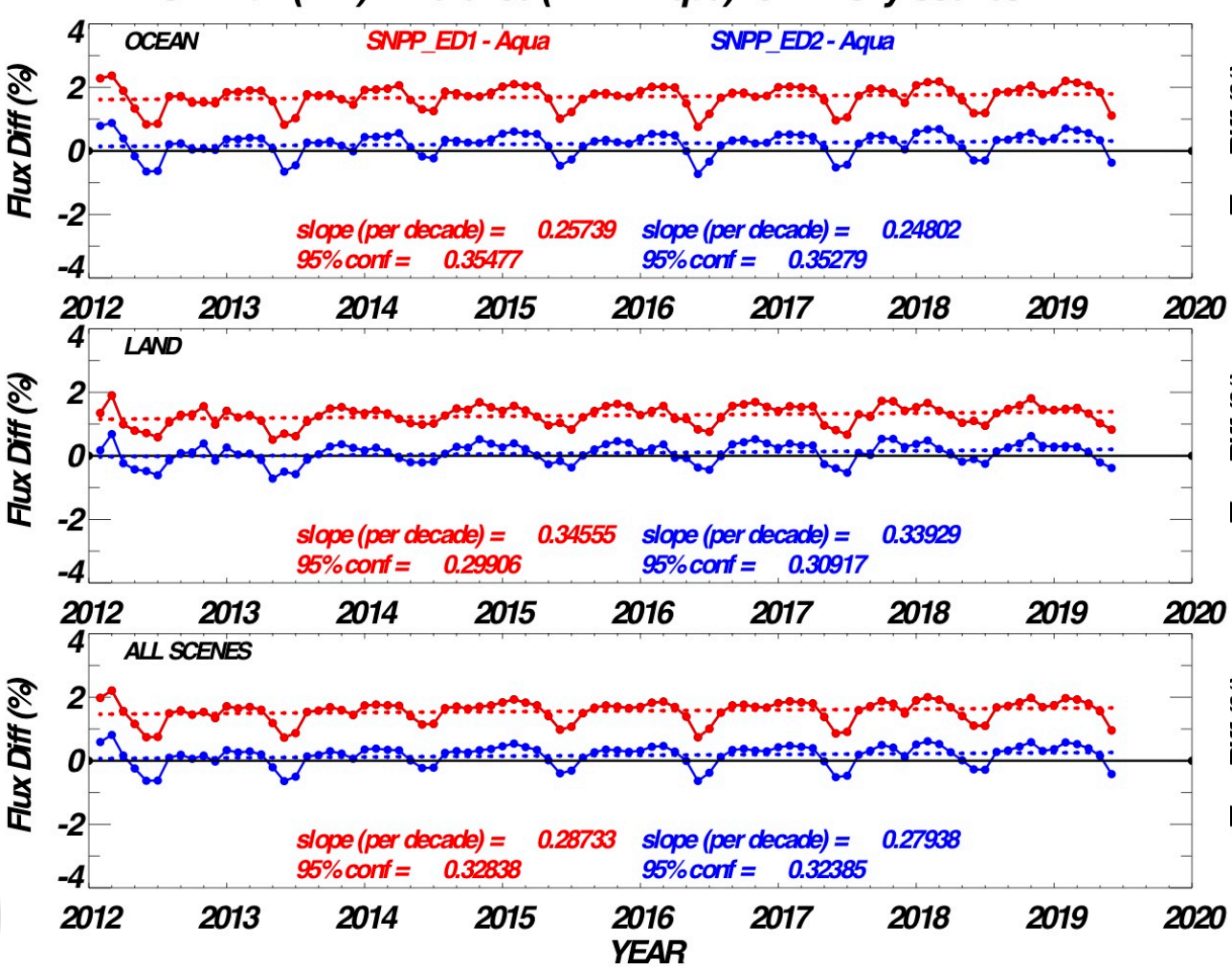
FM5 Edition 2

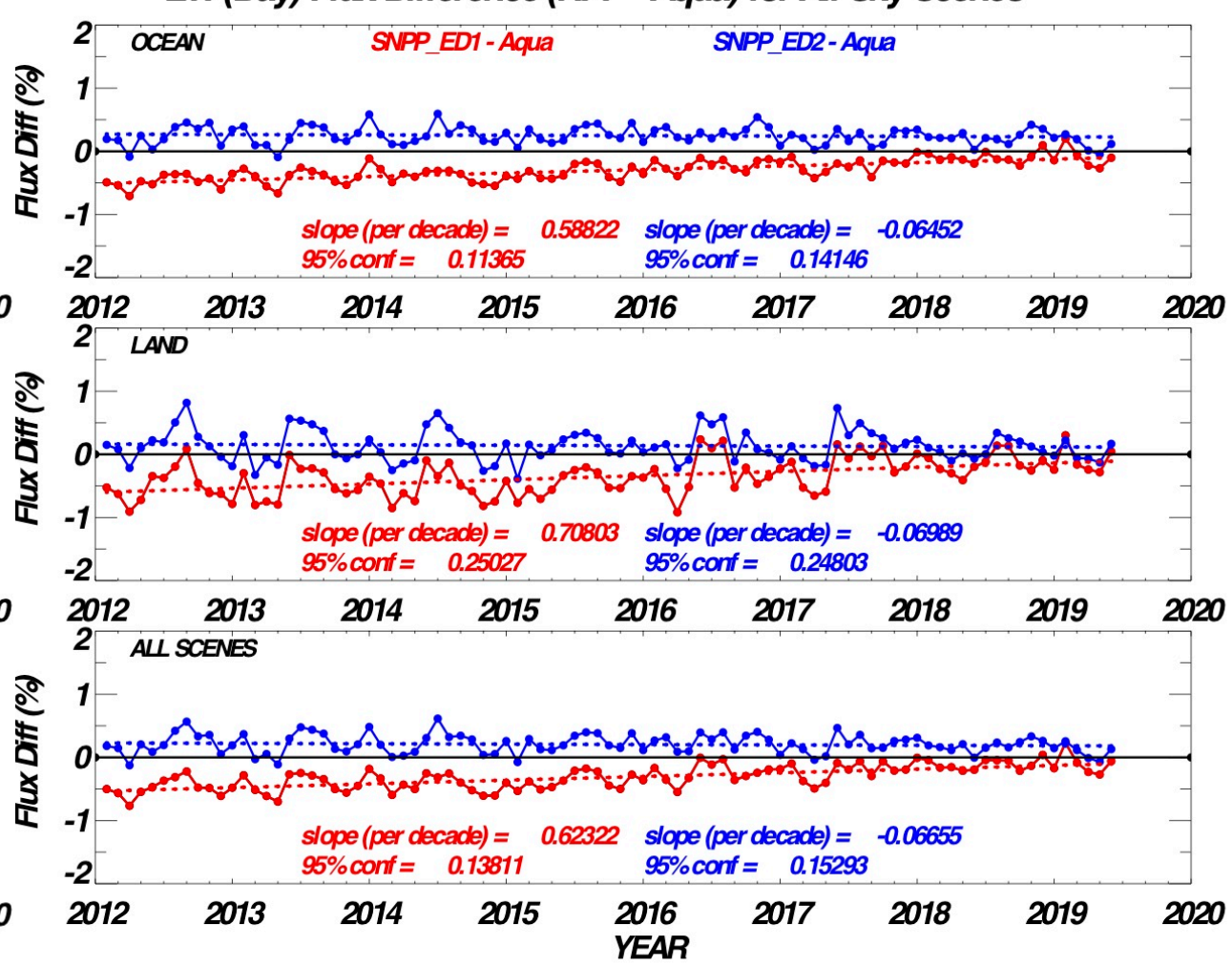
- **The Beginning of Mission (BOM) SRF for FM5 was adjusted to radiometrically scale the SW for FM5 to FM3 in 2014 for global all-sky, all scenes based on inter-comparison data.**
  - Re-evaluated the pre-launch instrument test data and used a Lagrange multiplier based optimization approach to obtain optimal solution.
  - TOT channel did not require any BOM adjustments.
- **Observed a small upward long-term trend in the LW day validation studies.**
- **Used the regression between the LW (Day-Night) and WN (Day-Night) for Ocean and Land scenes to adjust the SW/TOT SRF using the functional form:**

$$D(\lambda) = [1 - e^{-\alpha\lambda}] + \beta$$

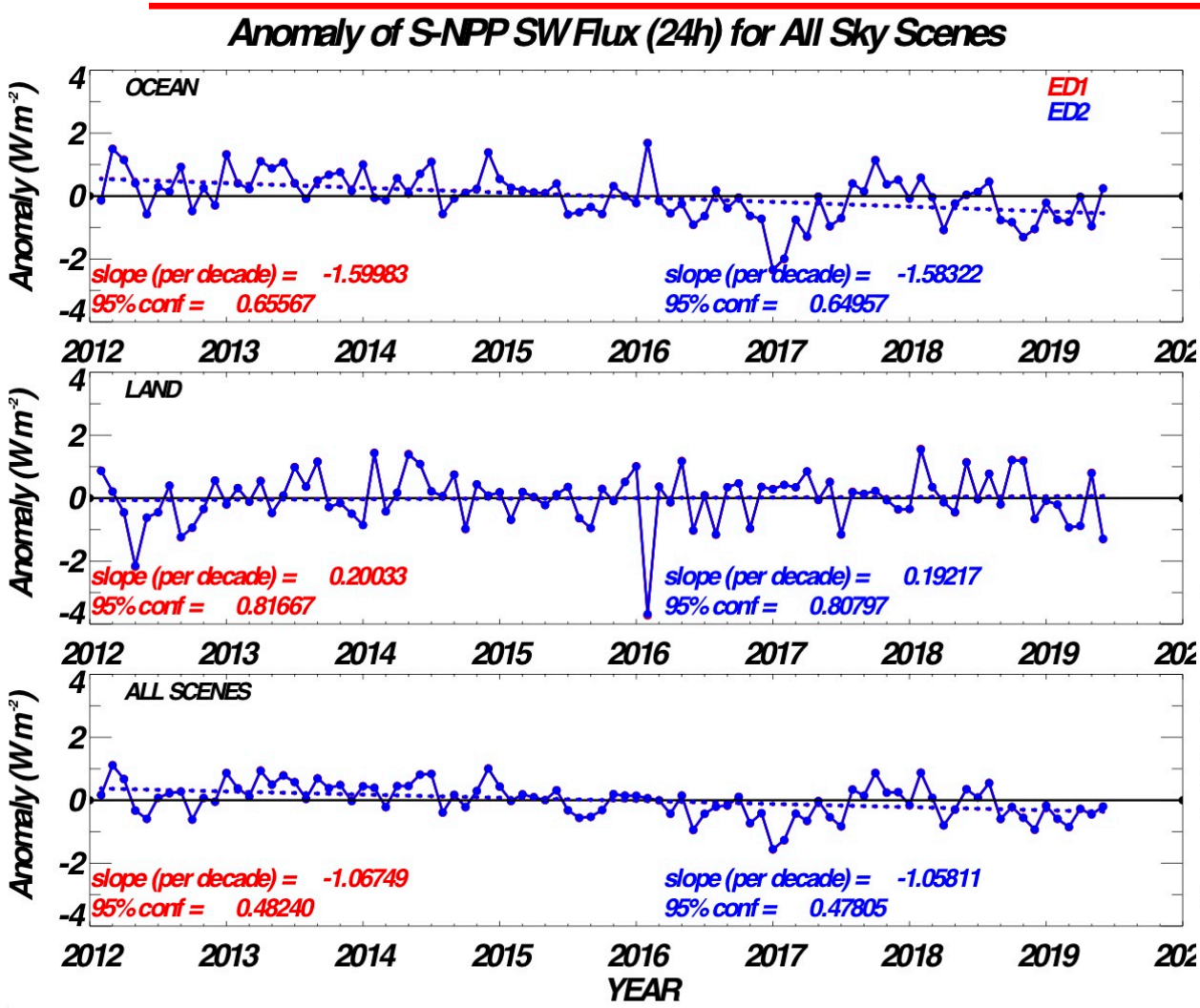
Validation: S-NPP – Aqua (Ed 4) Flux difference

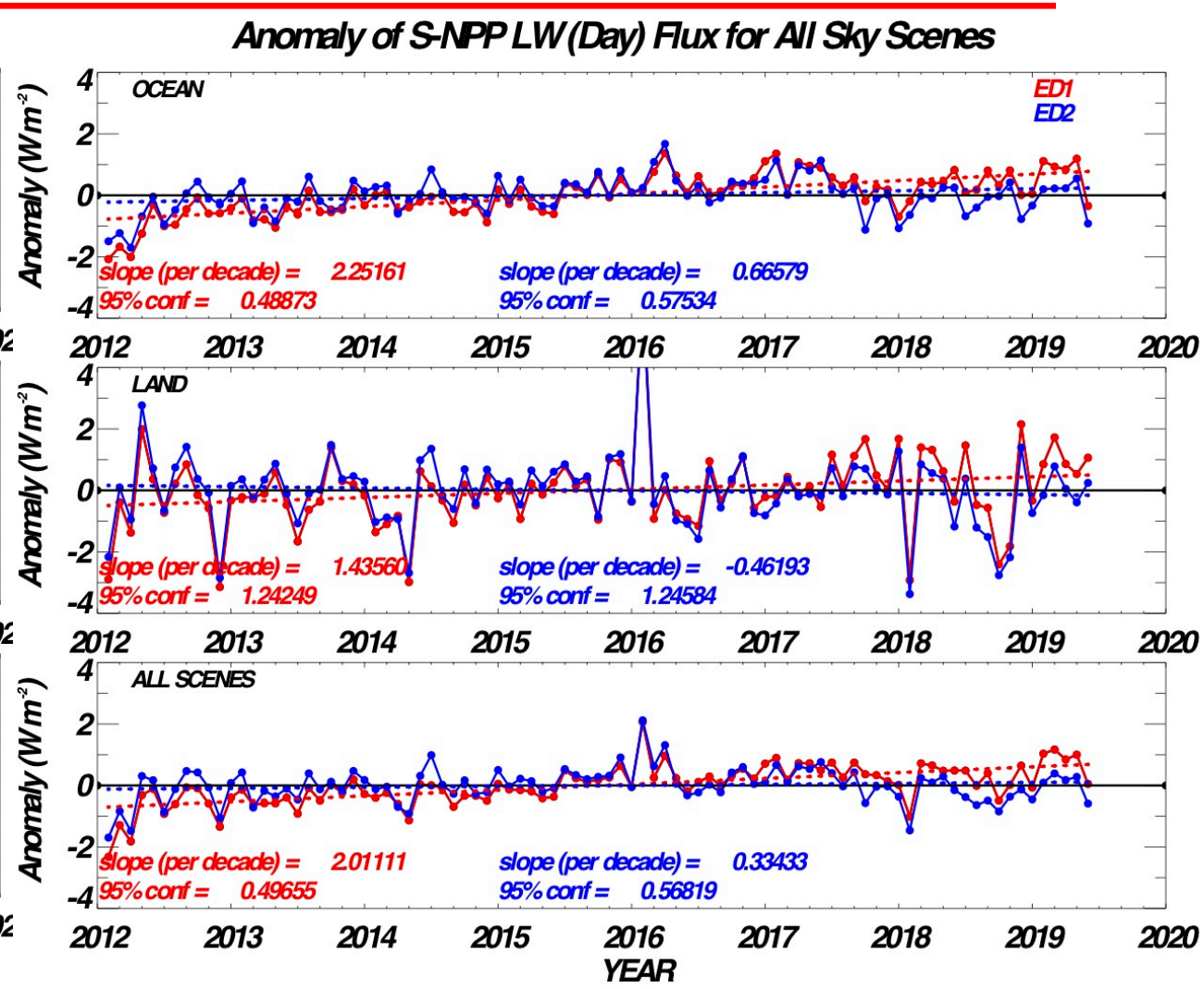
FM5 Edition 2 shows more consistency with the Aqua/FM3 instrument (Ed4) at BOM as well as long term.



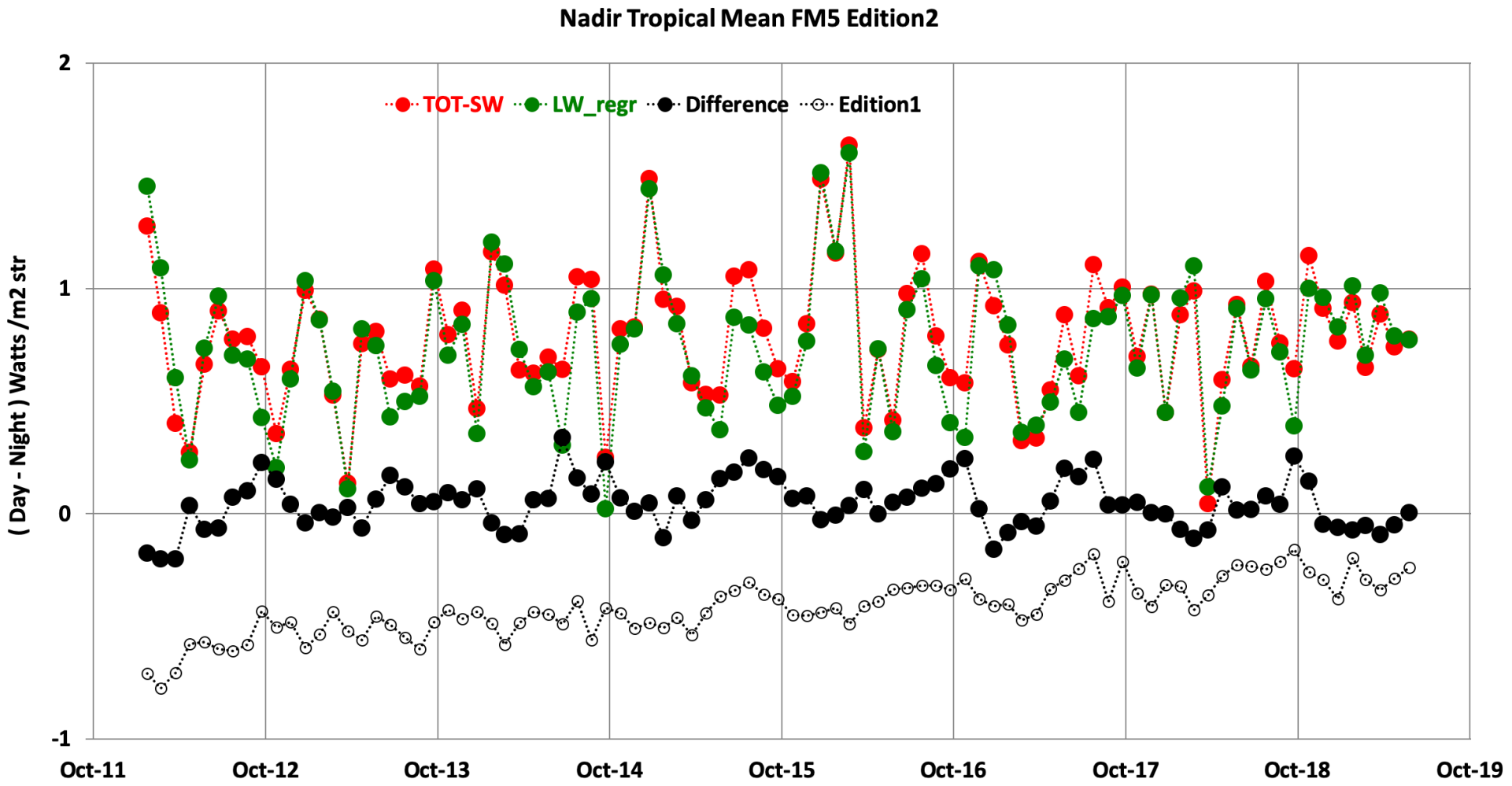


Validation: FM5 SW and LW day Anomalies





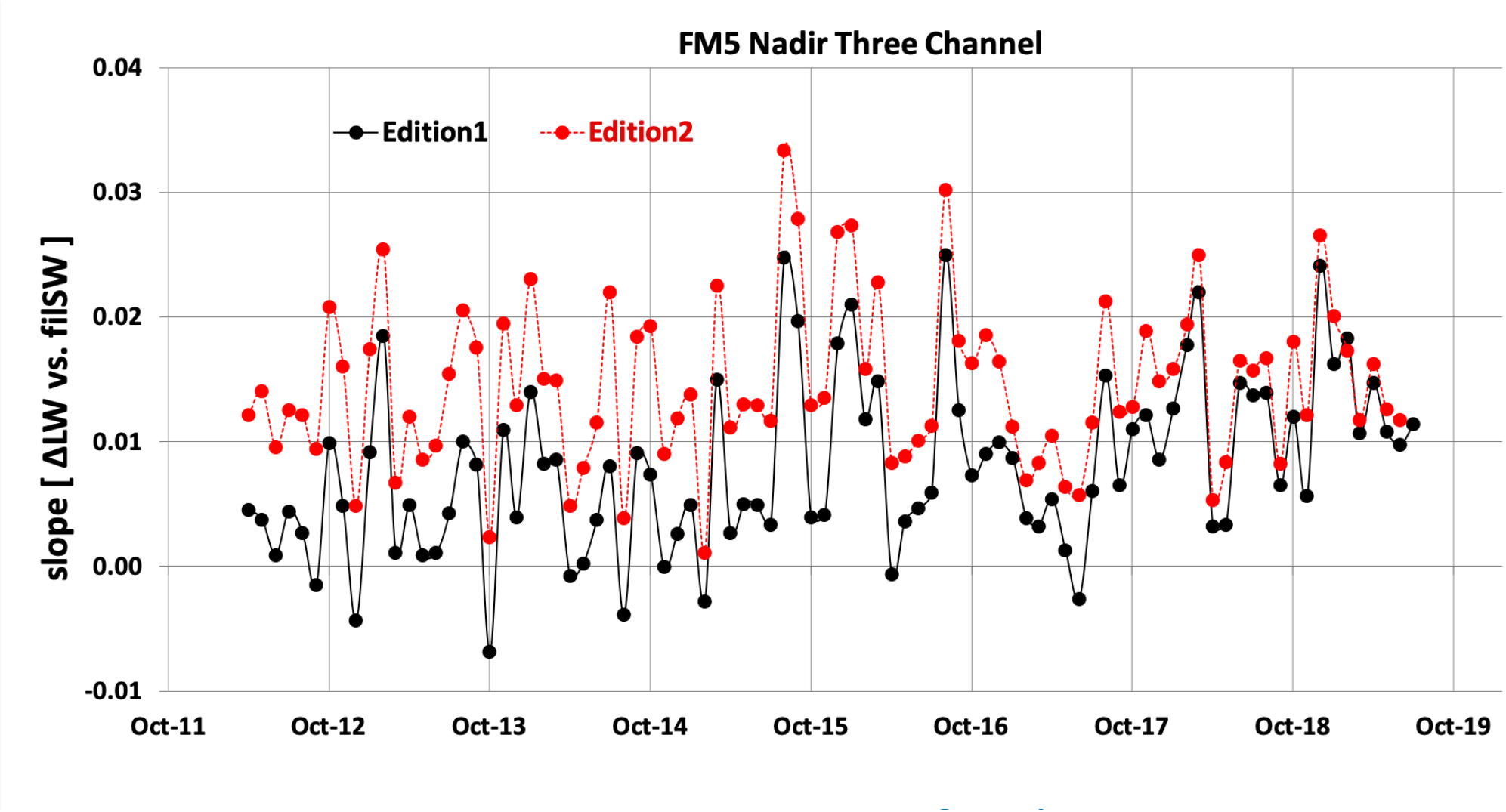
Validation- FM5 Tropical Mean



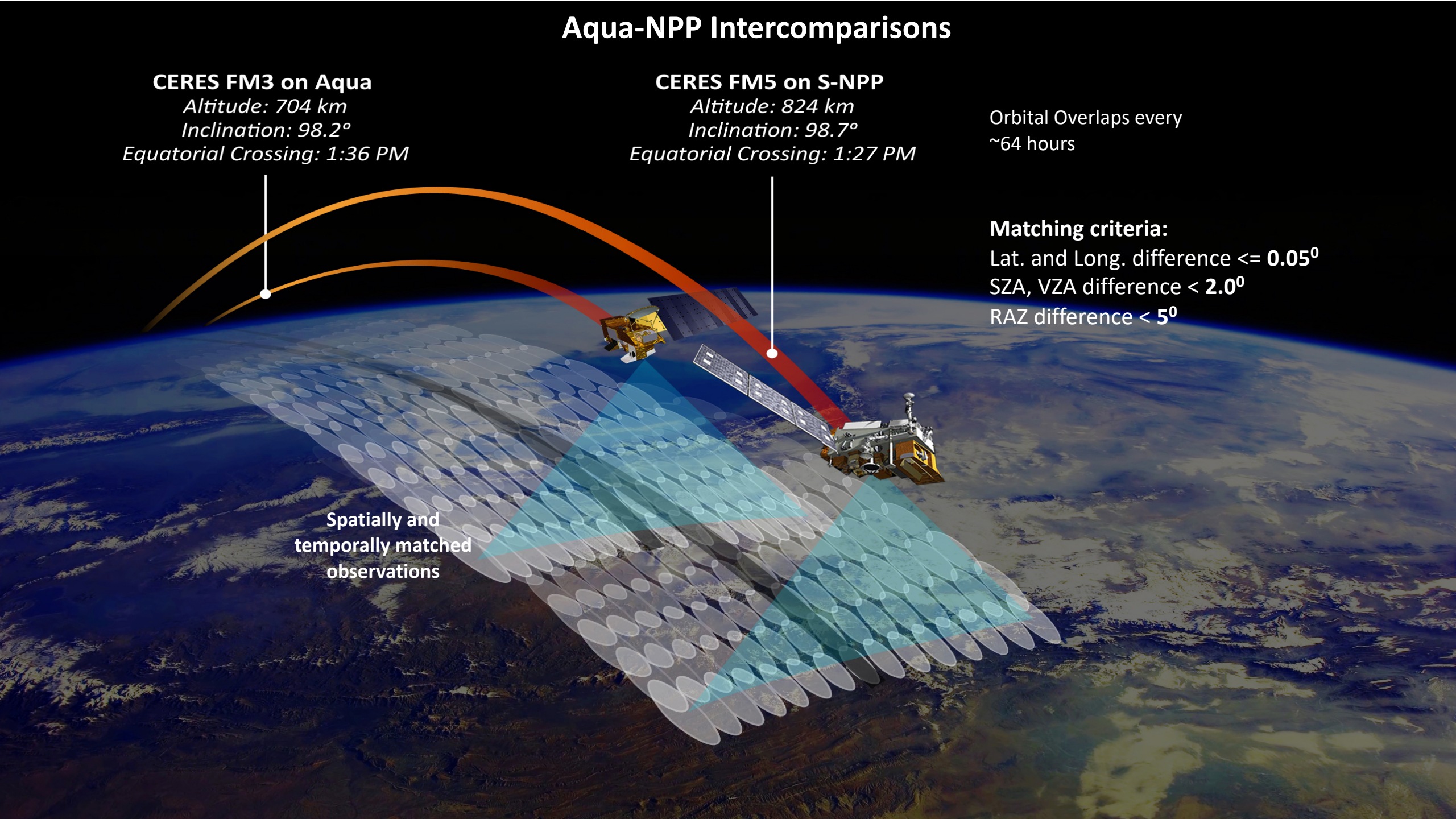
Validation: DCC 3-Channel Intercomparison

- Compare the radiances from the three sensors of the instrument when viewing Deep Convective Clouds (DCC).
- Two sets of longwave (LW) radiances obtained:
  - TOT and SW sensors
  - Trained WN sensor
- The trend between the difference of the two LW radiances and the SW radiance is monitored over time.
- Highlights inconsistencies in the relationship in the response functions of the SW sensor and the shortwave part of the TOT sensor.

DCC 3-Channel Intercomparison



Aqua-NPP Intercomparisons



Orbital Overlaps every ~64 hours

Matching criteria:

Lat. and Long. difference <= **0.05^0**

SZA, VZA difference < **2.0^0**

RAZ difference < **5^0**

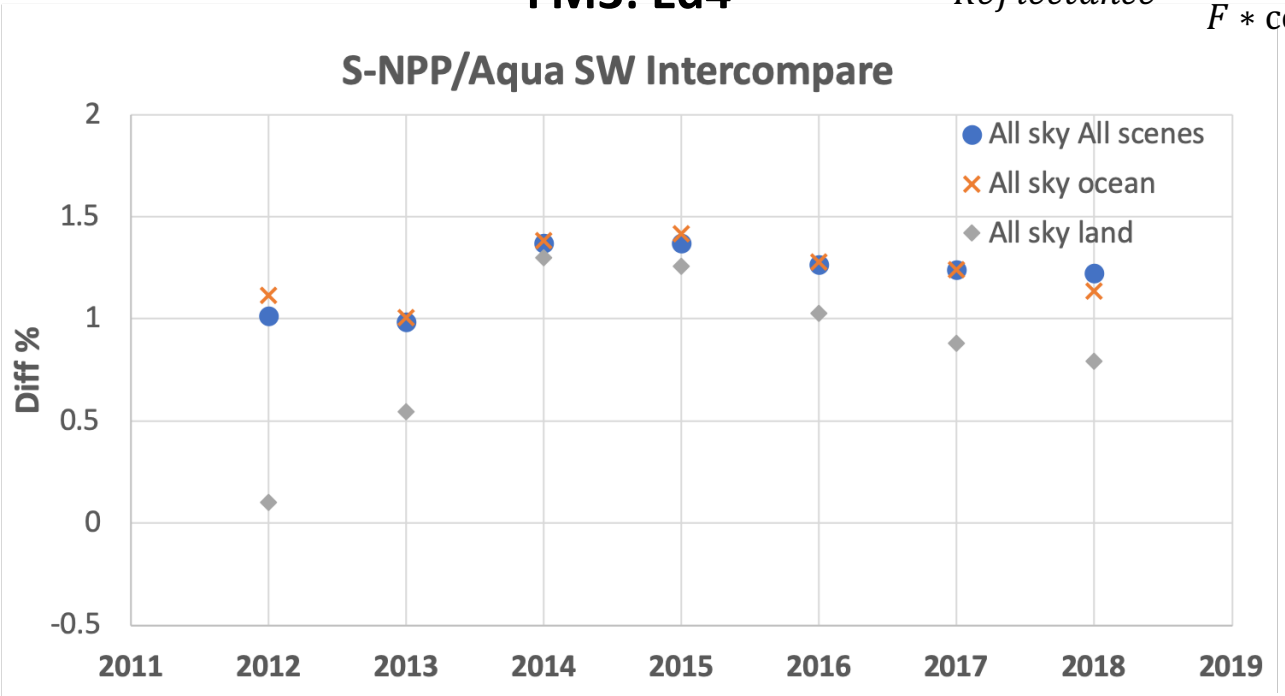
FM5/FM3 Inter-comparisons SW: 2012-2018

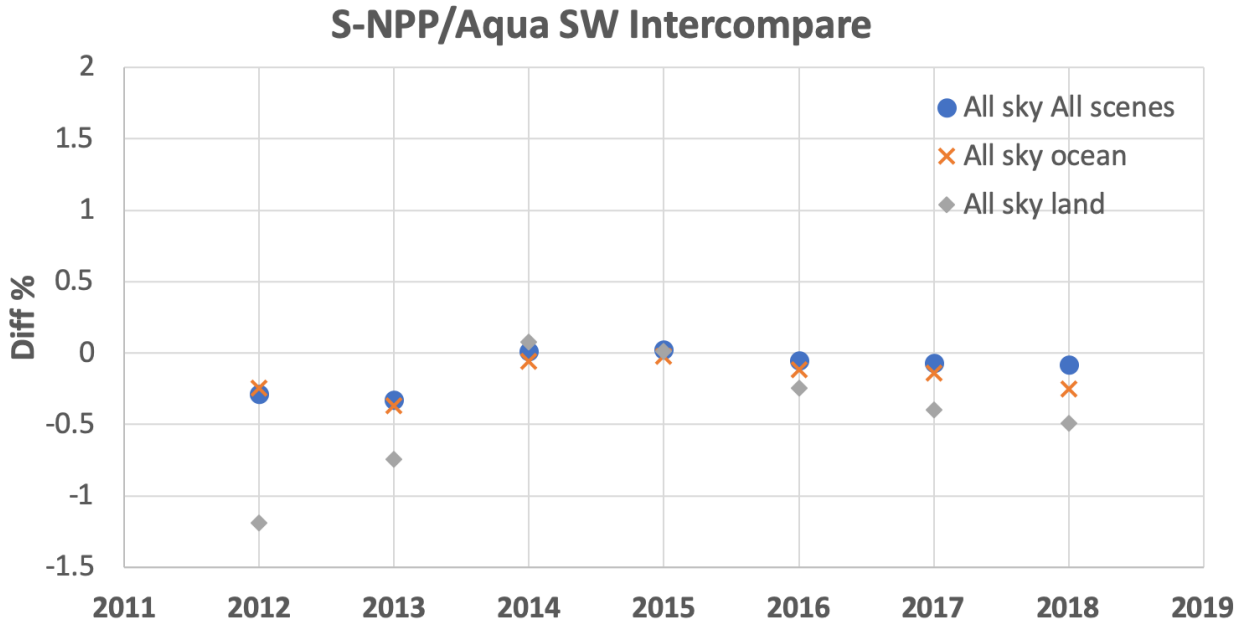
Difference of Reflectance:
FM5-FM3 %

FM5: Ed1
FM3: Ed4

$$Reflectance = \frac{SW_{rad} * \pi}{F * \cos(SZA)}$$ F=1361 W/m²

FM5: Ed2
FM3: Ed4





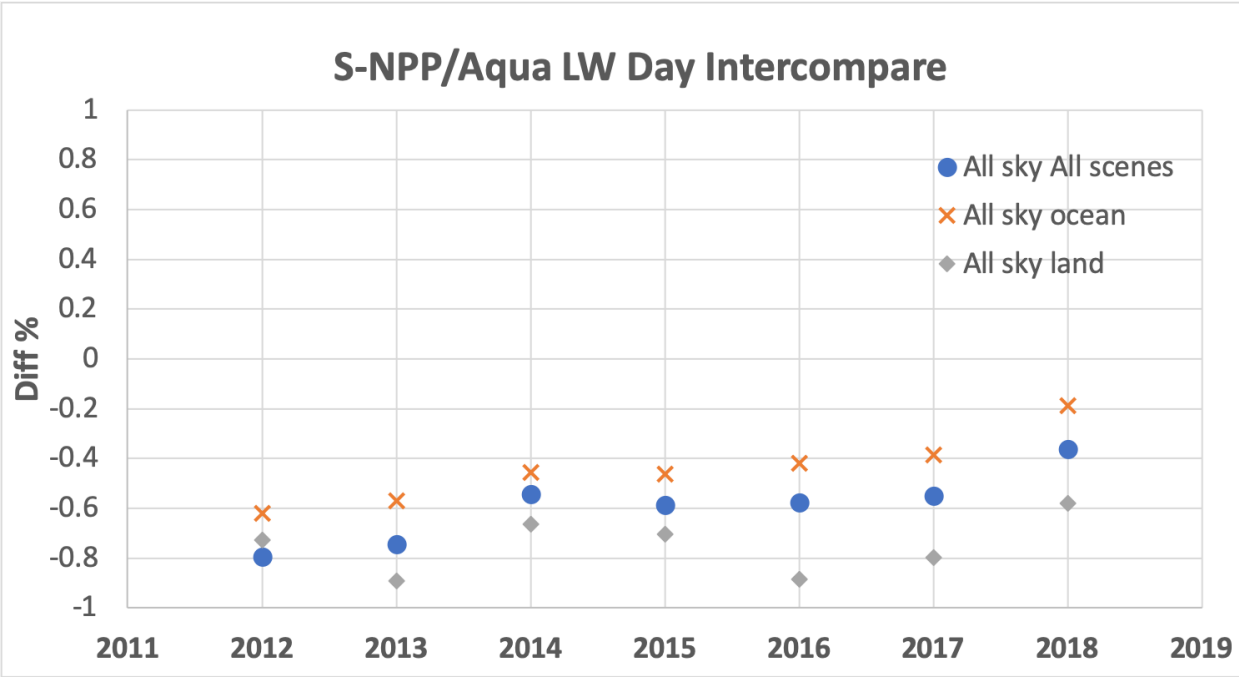
2014 data used for the radiometric scaling FM5 to FM3.

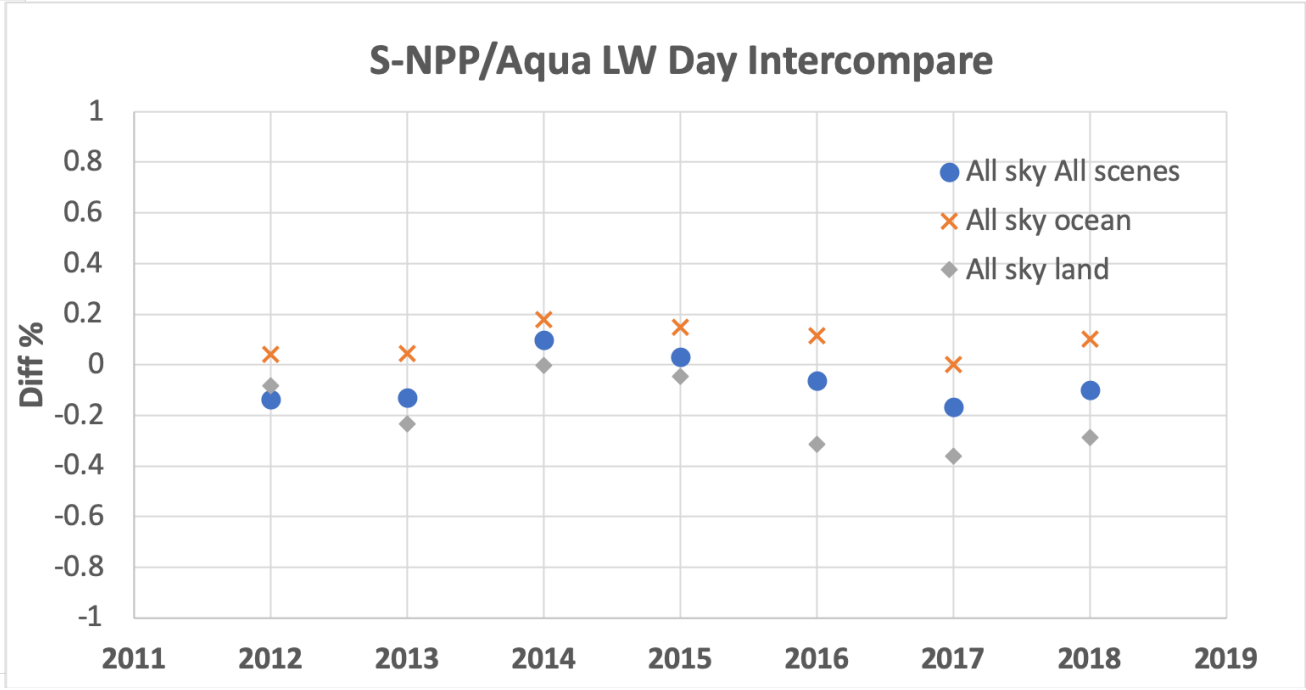
FM5/FM3 Inter-comparisons LW day: 2012-2018

FM5: Ed1
FM3: Ed4

Difference of Radiance:
FM5-FM3 %

FM5: Ed2
FM3: Ed4

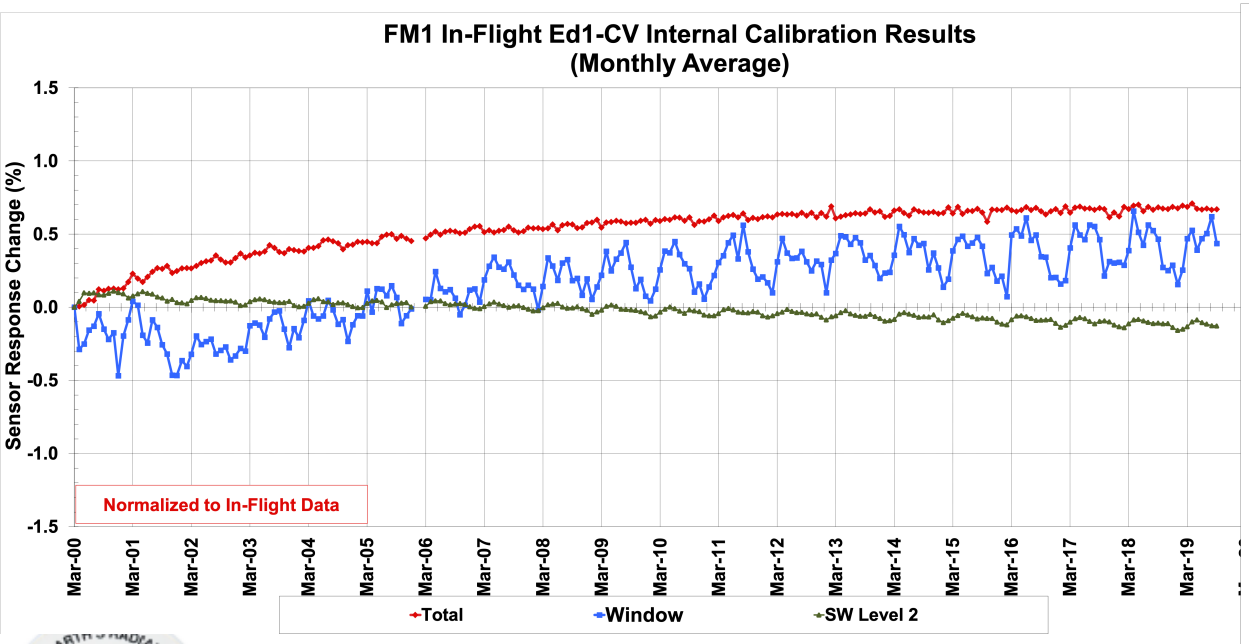


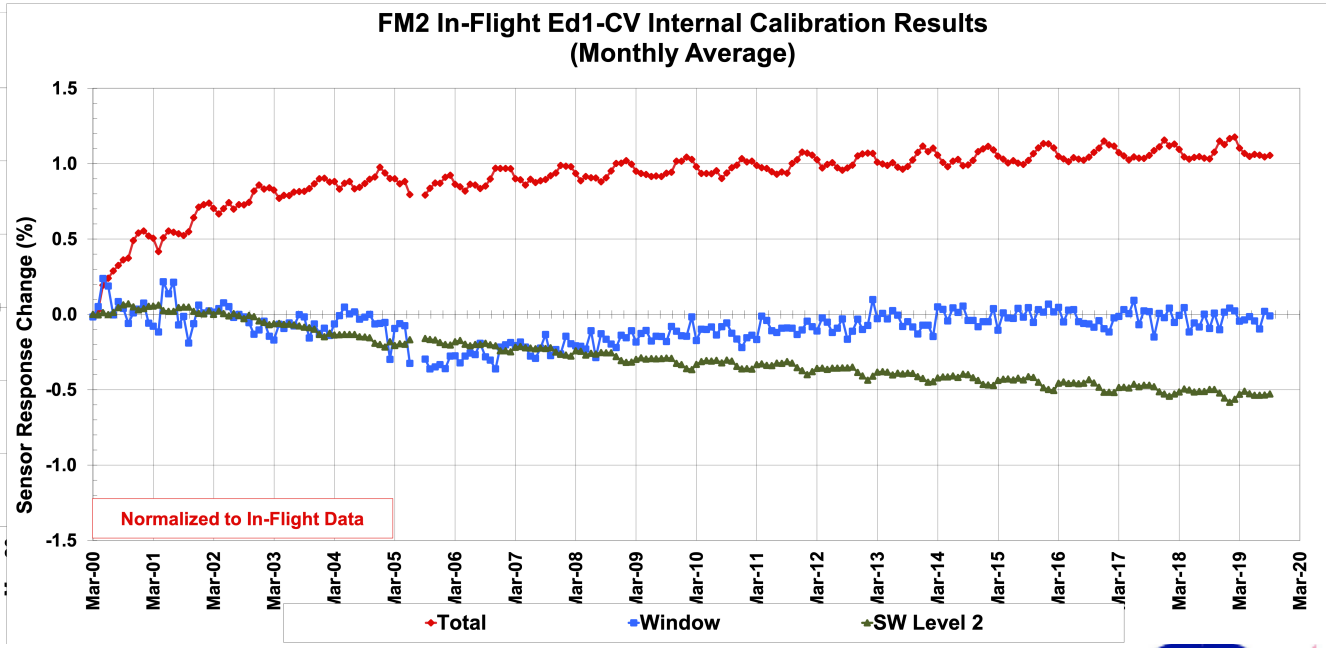


Terra & Aqua Instruments' Status
CERES FM1-FM4

Terra- FM1 & FM2 Internal Calibration

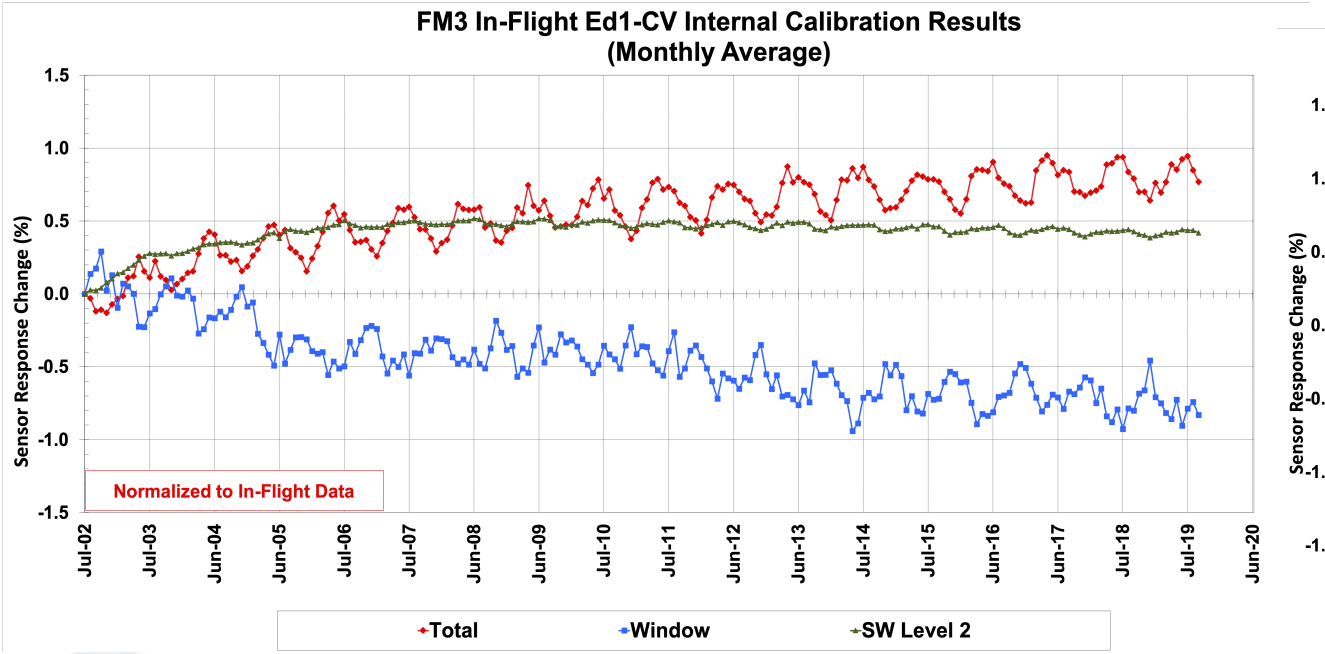
- **For FM1, TOT channel shows ~0.6% rise, SW channel shows ~0.1% drop, and WN channel shows ~0.5% rise after initial drop.**
- **For FM2, TOT channel shows ~1% rise, SW channel shows ~0.5% drop, while WN channel shows ~0% change since start of mission.**

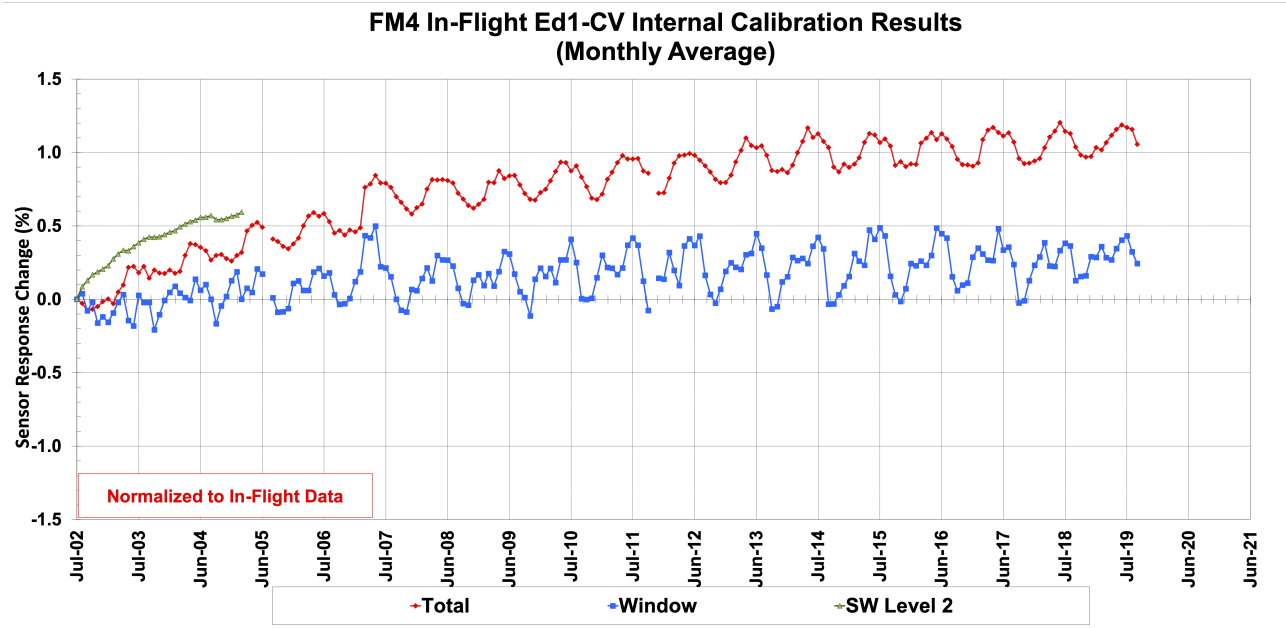




Aqua- FM3 and FM4 Internal Calibration

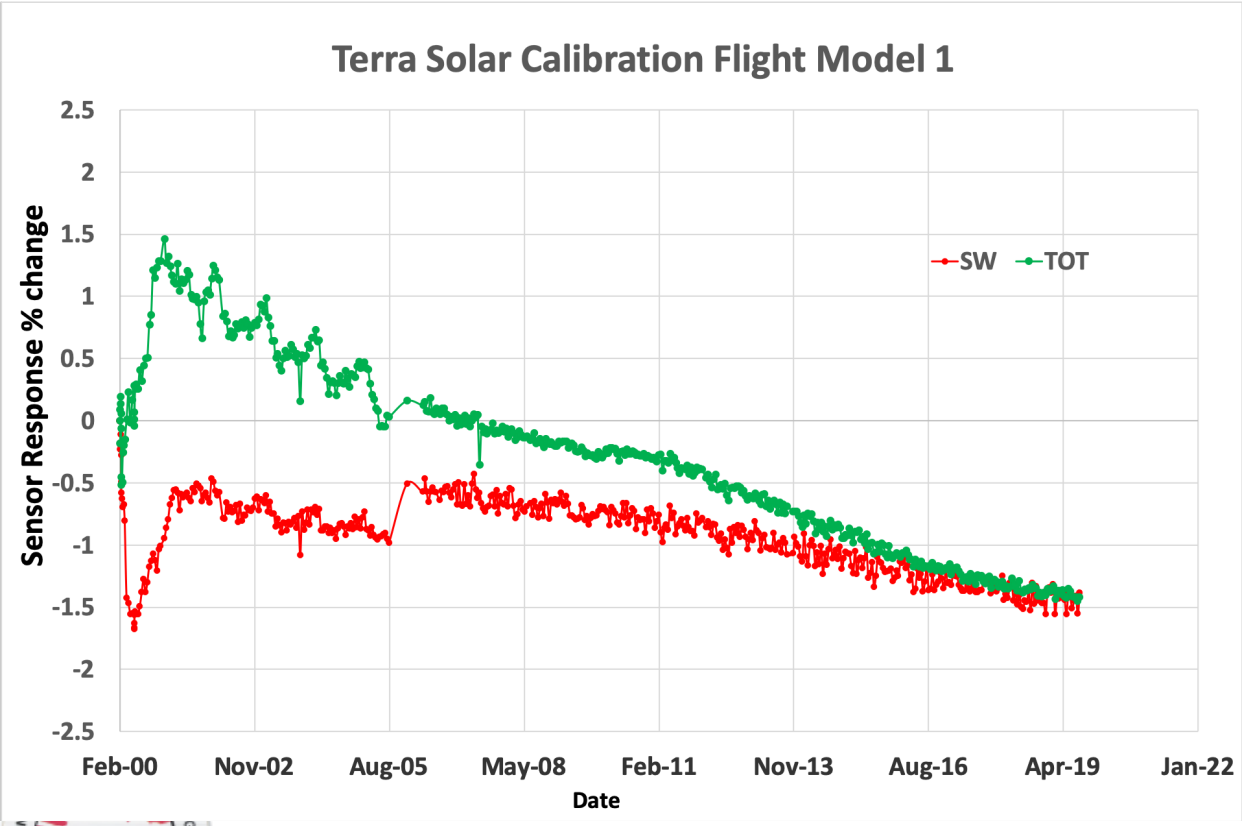
- **For FM3, TOT channel shows ~0.8% rise, SW channel shows ~0.5% rise, and WN channel shows ~0.8% drop.**
- **For FM4, TOT channel shows ~1% rise, while WN channel shows ~0.25% rise.**

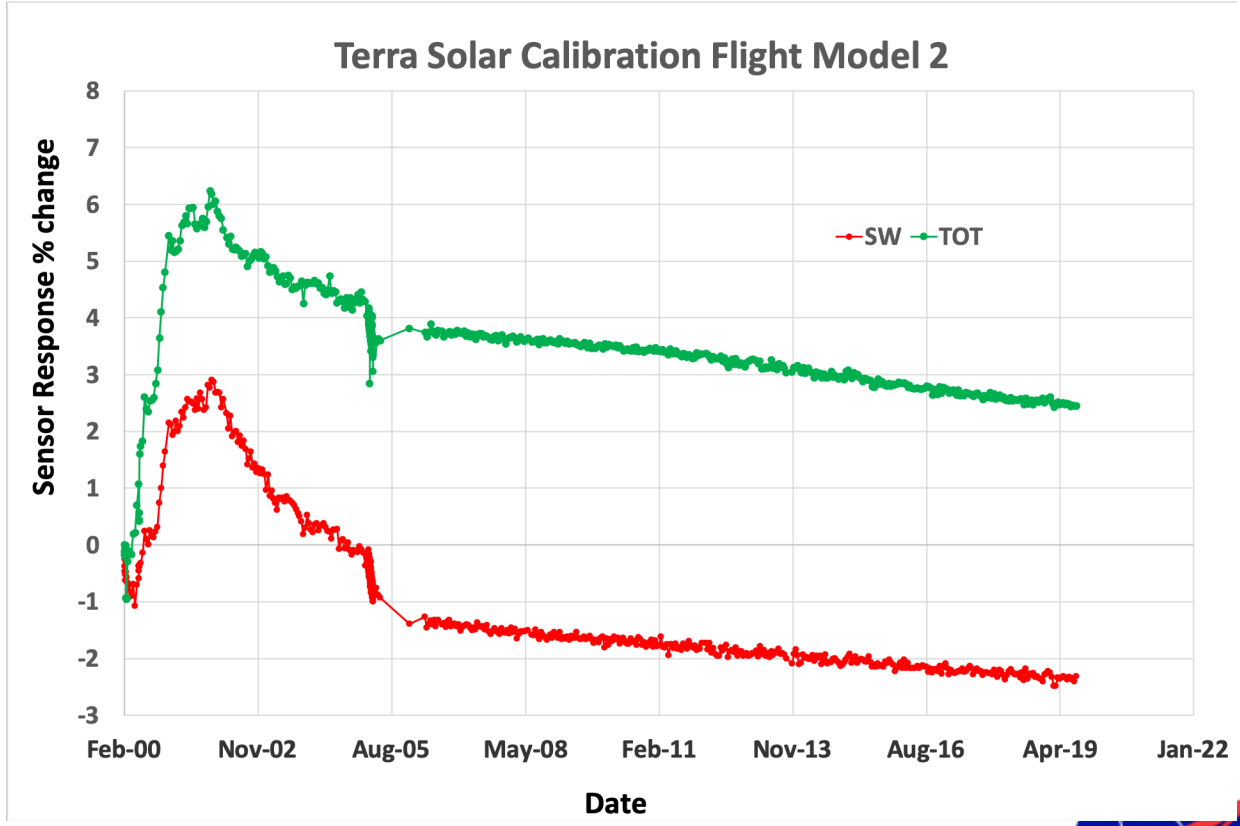




Terra- FM1 & FM2 Solar Calibration

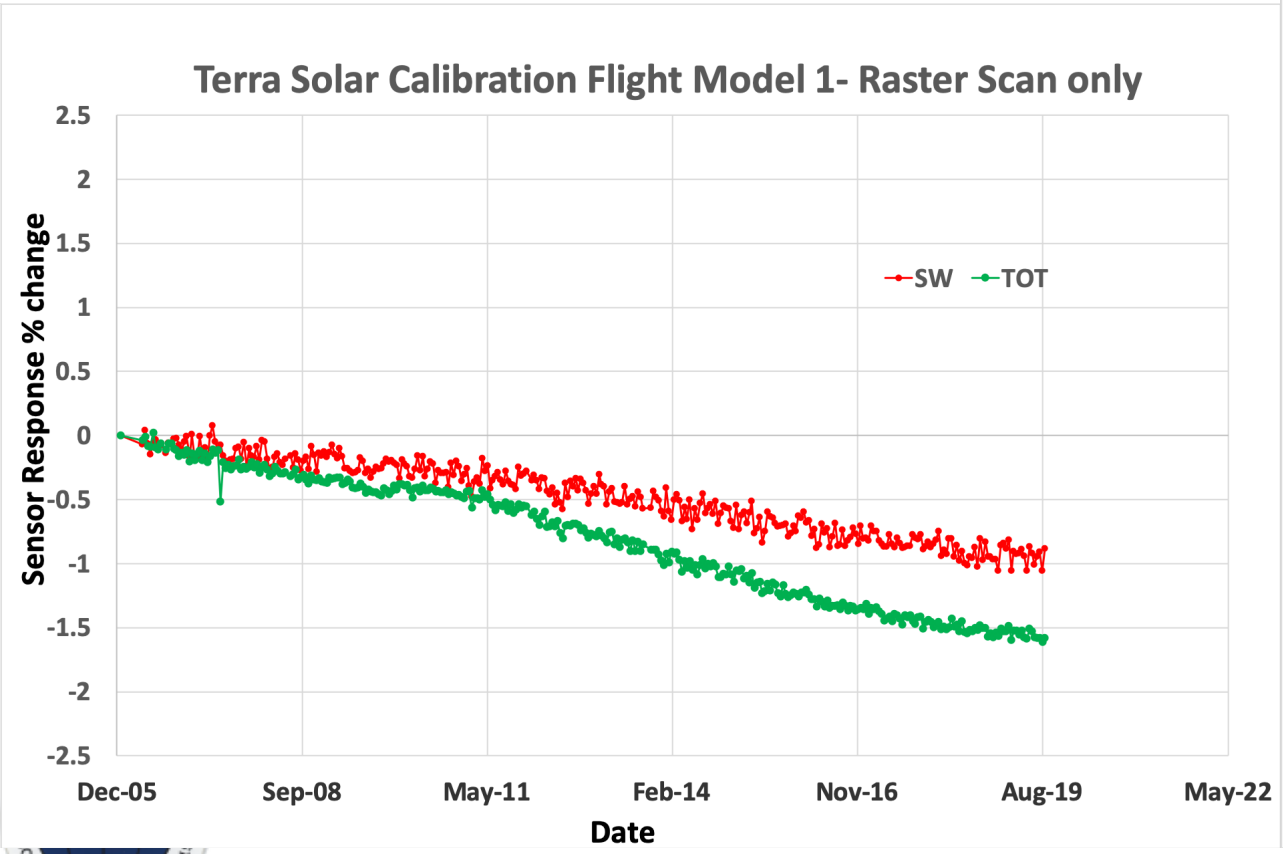
Revisiting the analysis for solar calibration for all instruments.

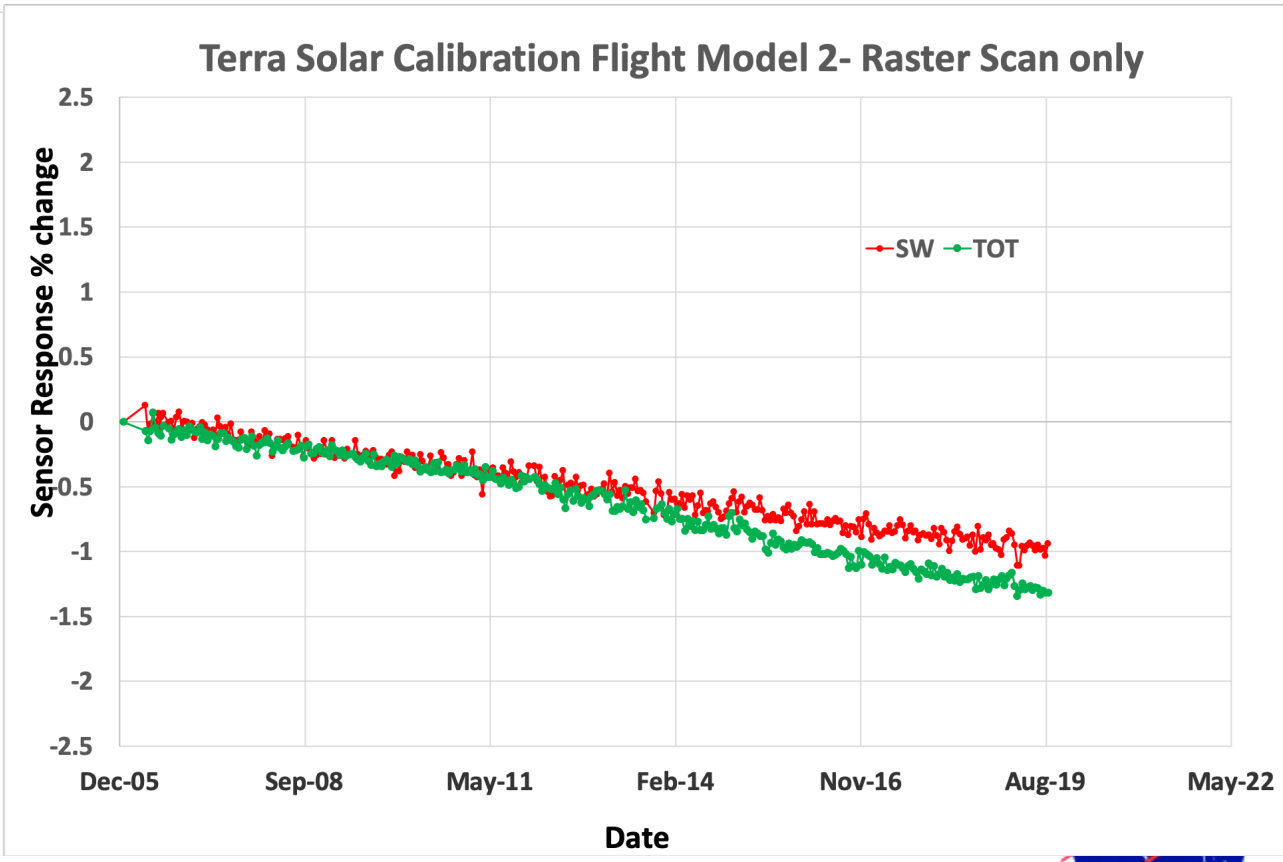




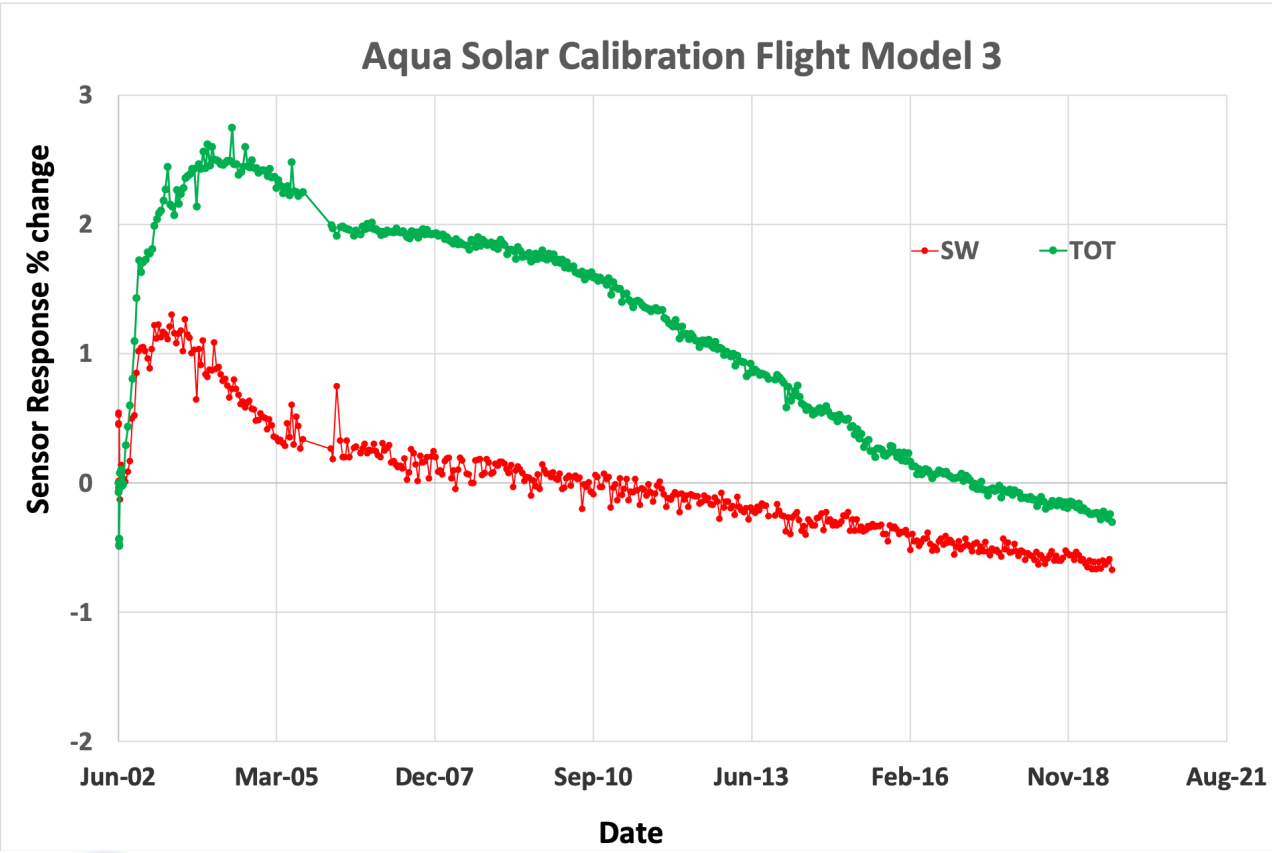
Terra- Solar Calibration, Raster Scan only

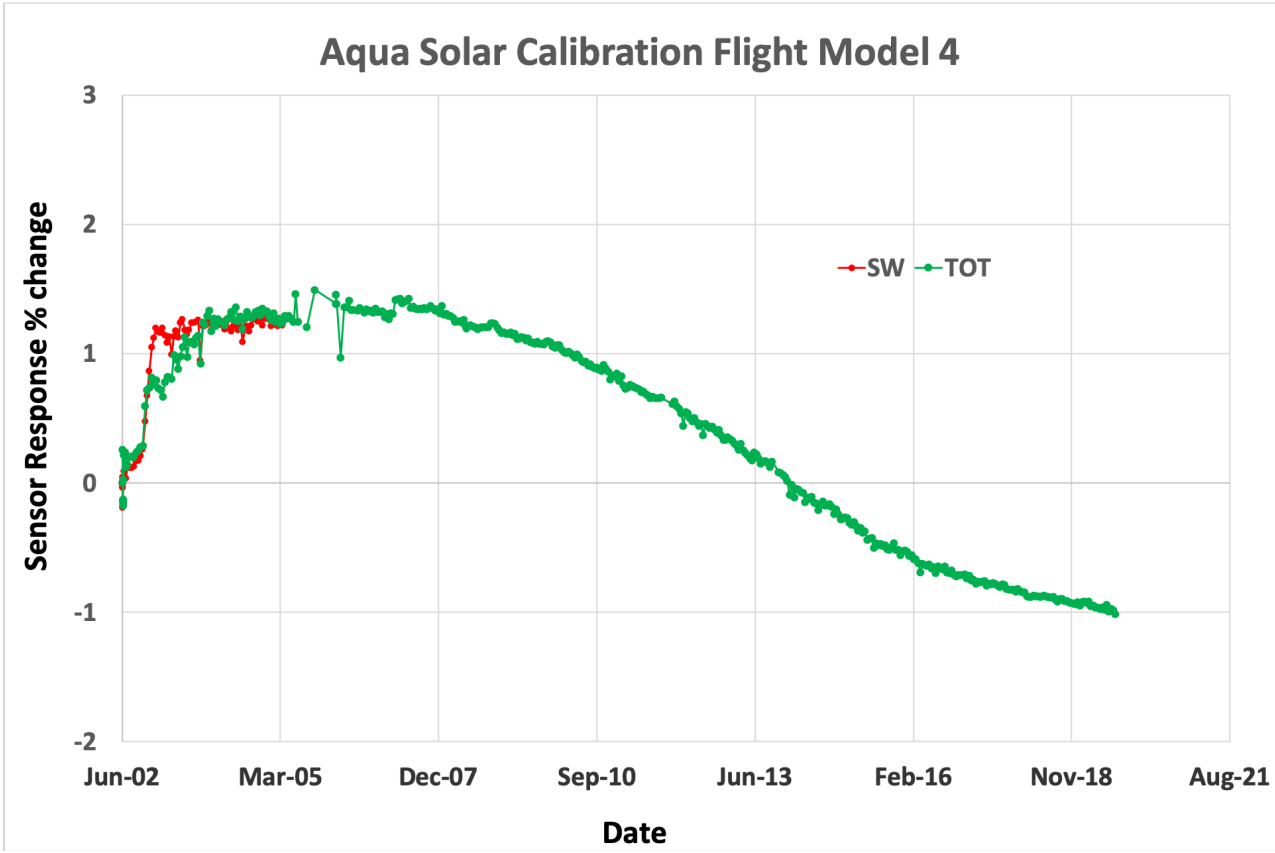
- **Since the transition over to raster scan for solar calibration, SW channel data shows a drop of response of ~1% and TOT channel shows a drop of ~1.5% for both FM1 and FM2 instruments.**
- **Focusing on the raster scan data and comparing with the internal calibration results.**





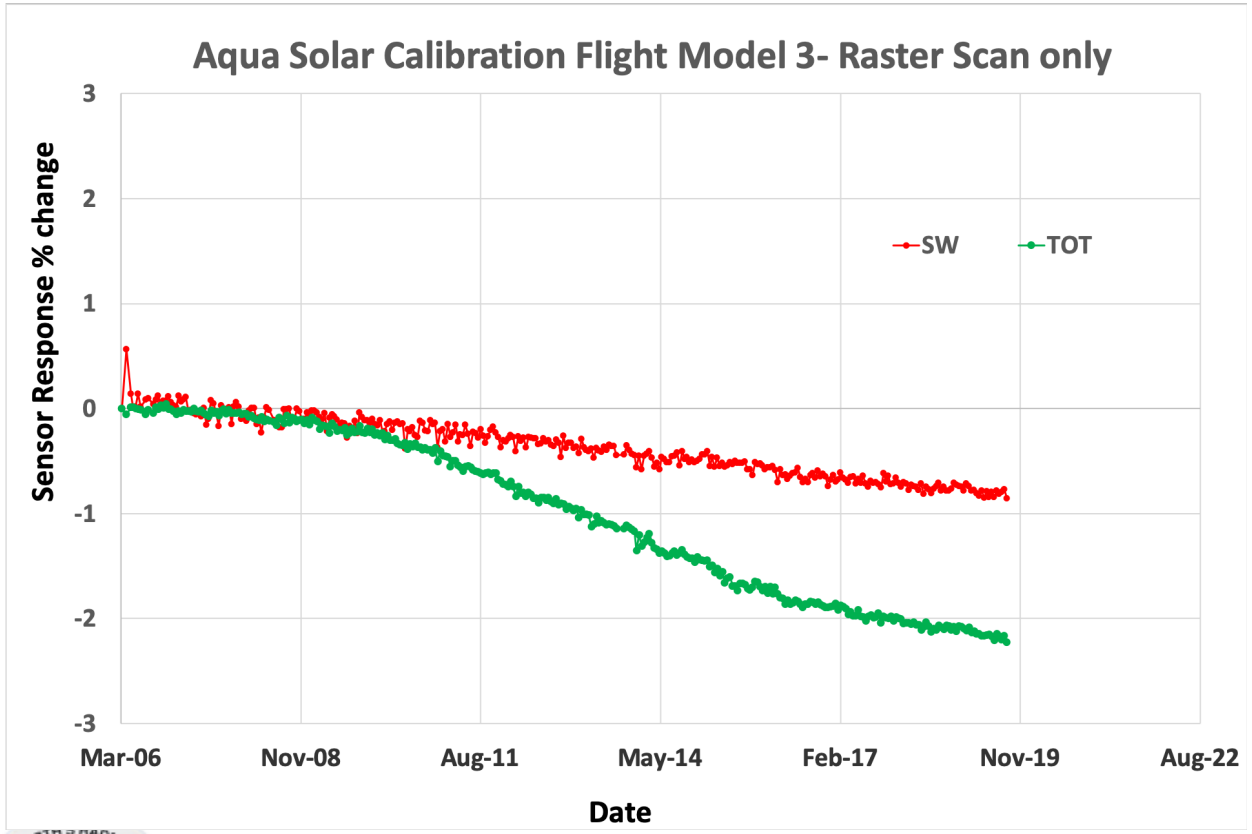
Aqua- FM3 & FM4 Solar Calibration

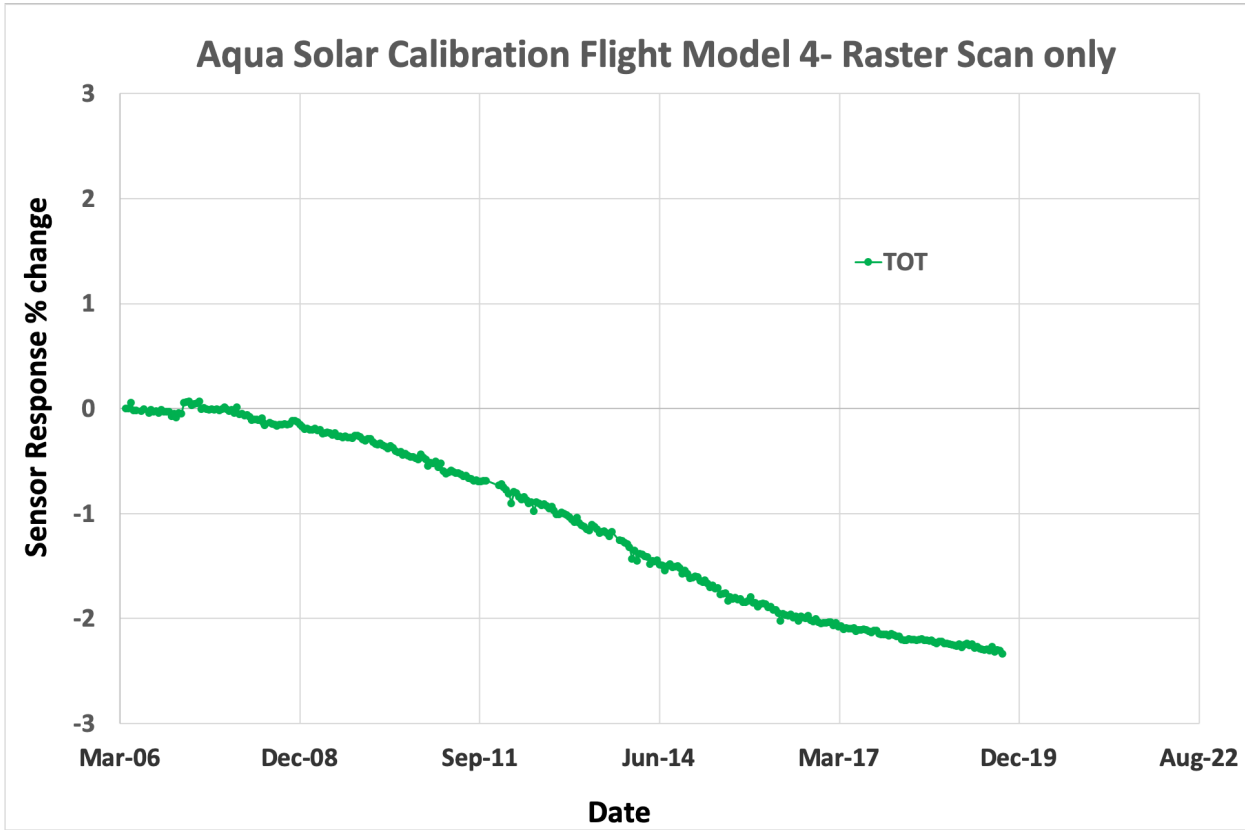




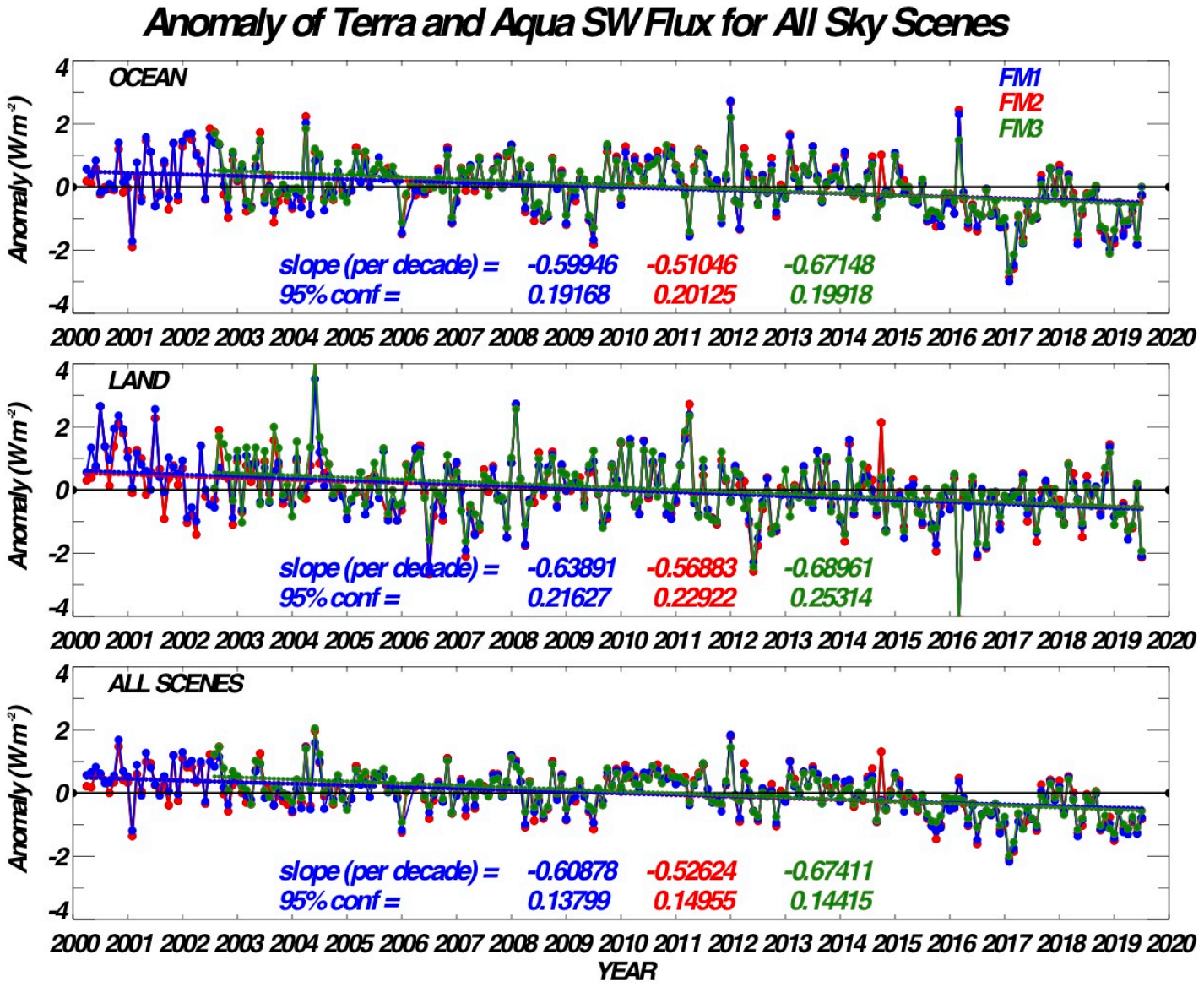
Aqua Solar Calibration, Raster Scan only

FM3 SW shows ~1% drop in response since start of raster scan.
TOT channel from both FM3 and FM4 show a similar 2% drop in response.



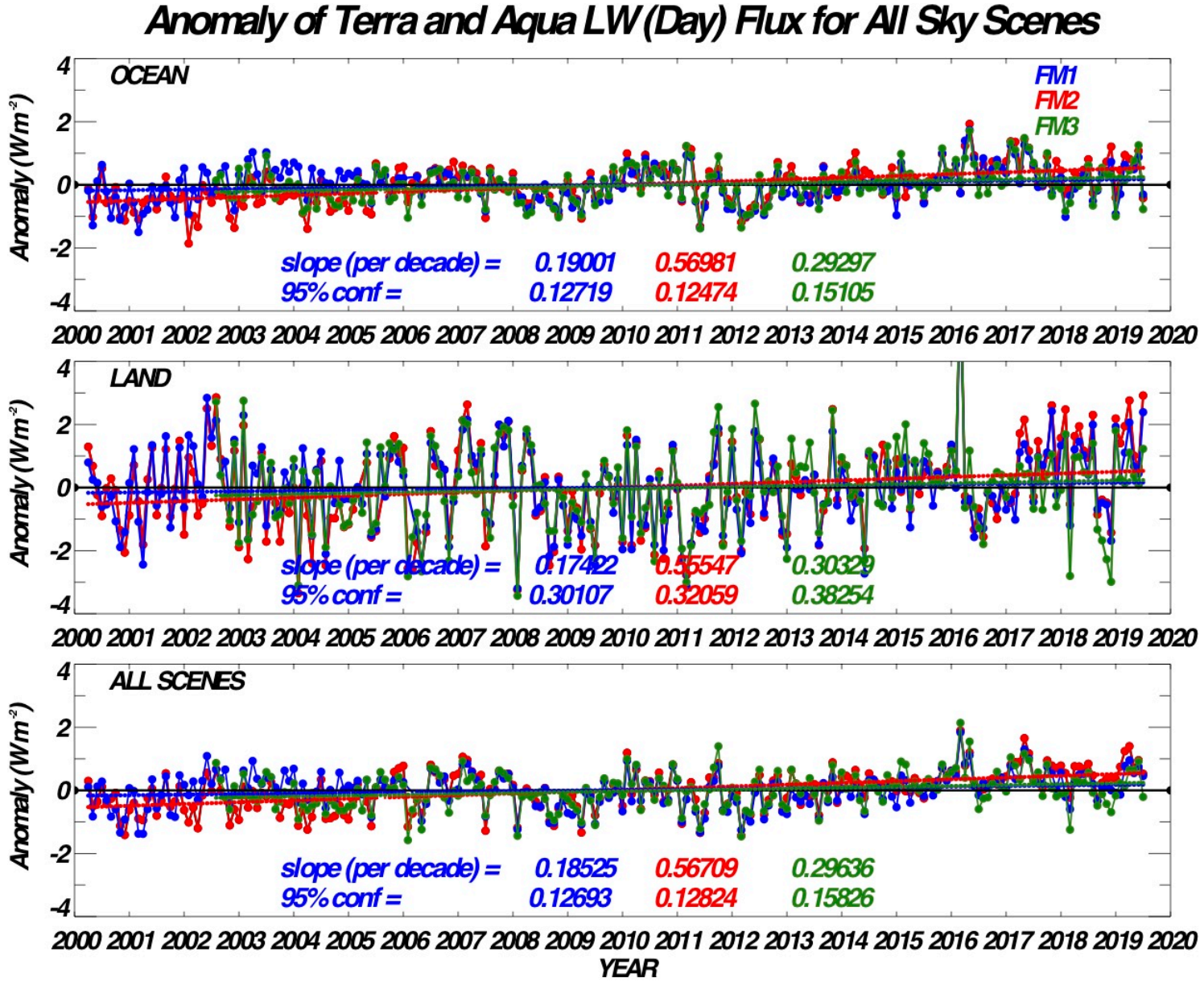


Validation: Terra and Aqua Ed-4 SW Flux Anomalies



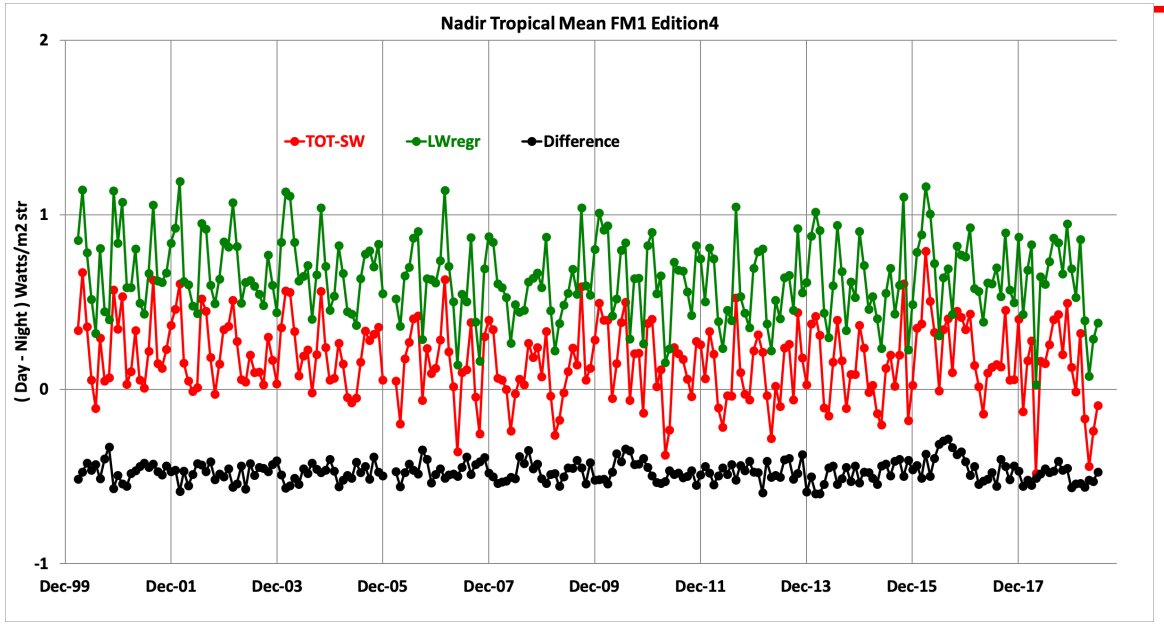
SW flux anomalies show similar trends for all three instruments

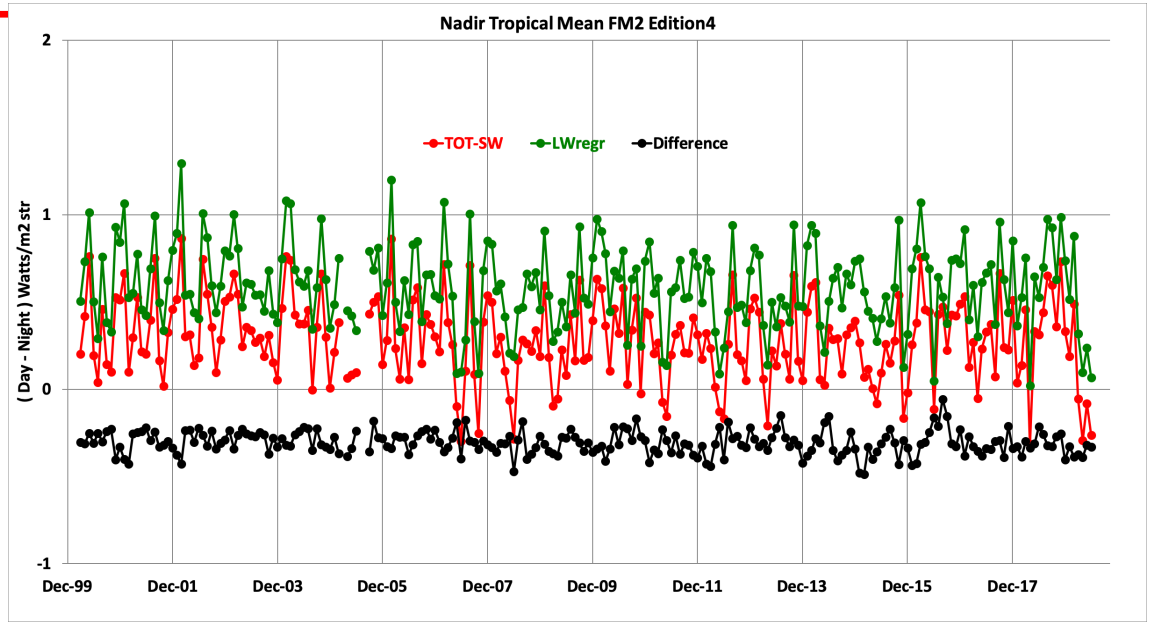
Validation: Terra and Aqua Ed-4 DLW Flux Anomalies

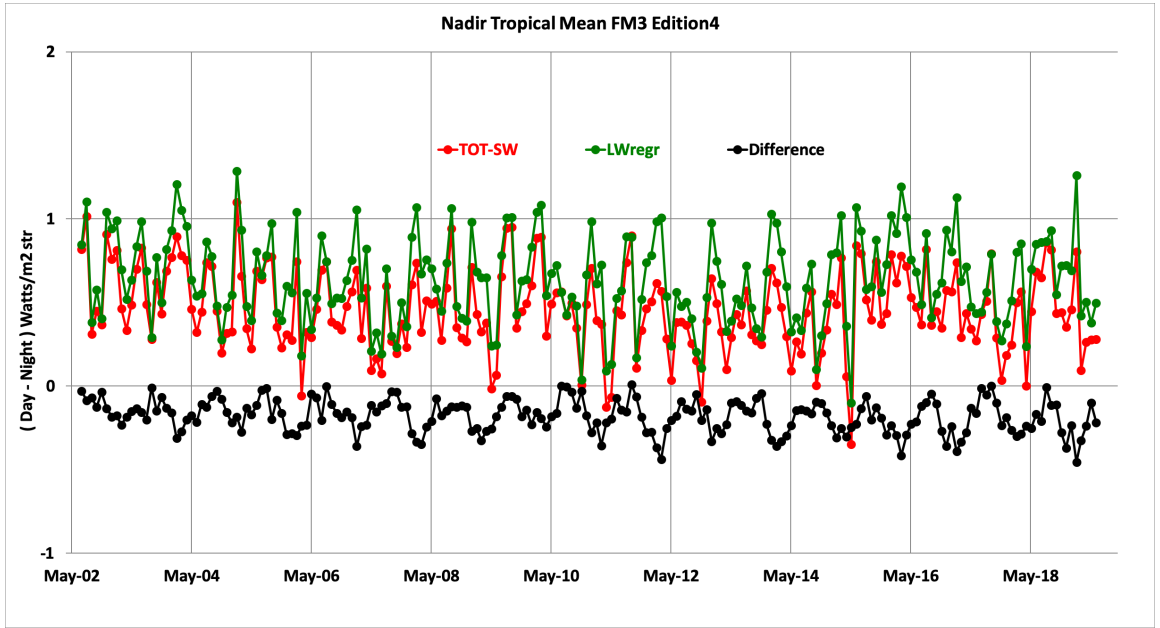


LW flux anomalies show similar trends for all three instruments

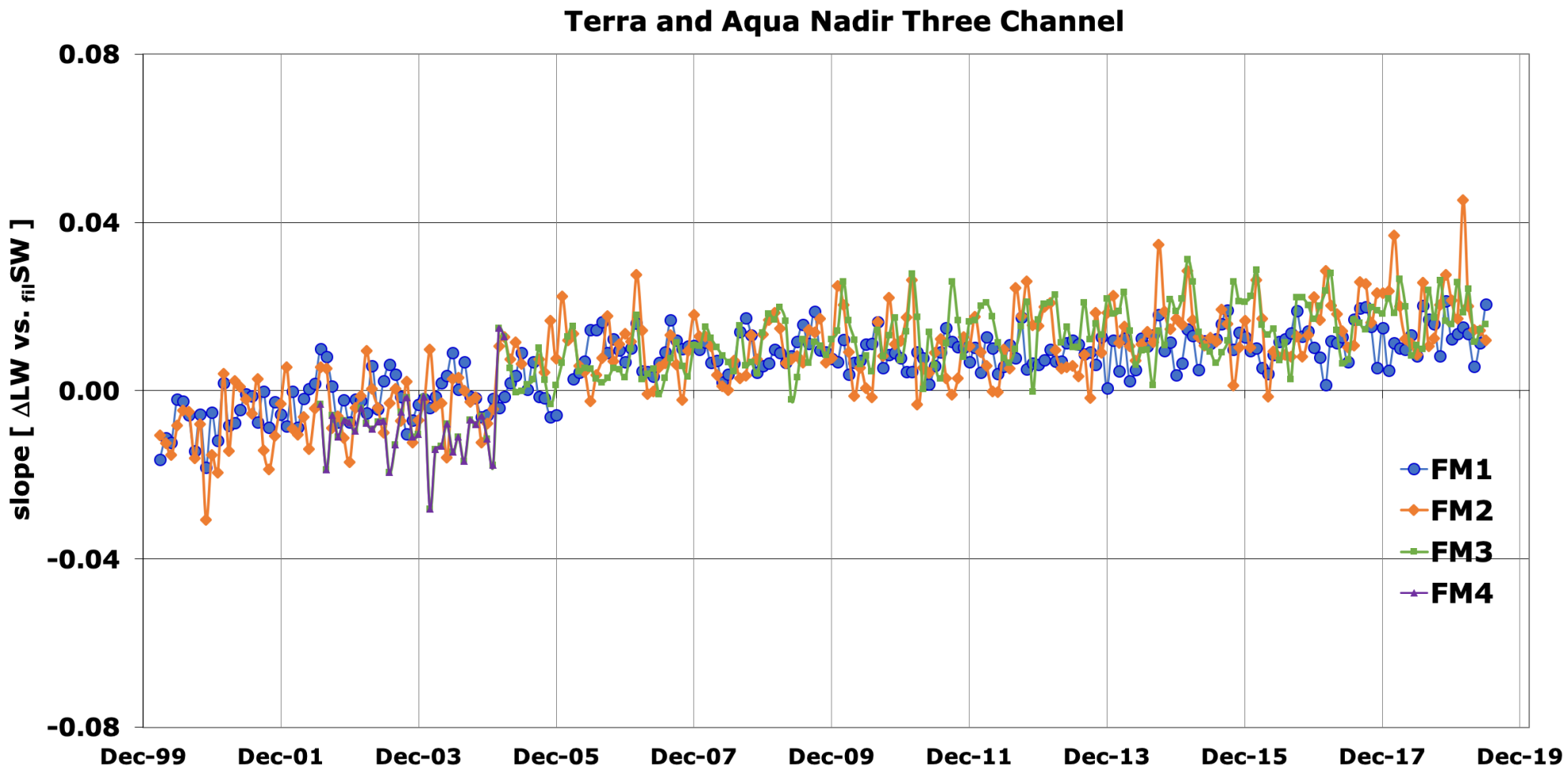
Validation- Terra and Aqua Tropical Mean







Validation- DCC 3-Channel Intercomparison

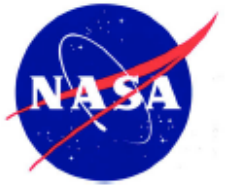


SUMMARY

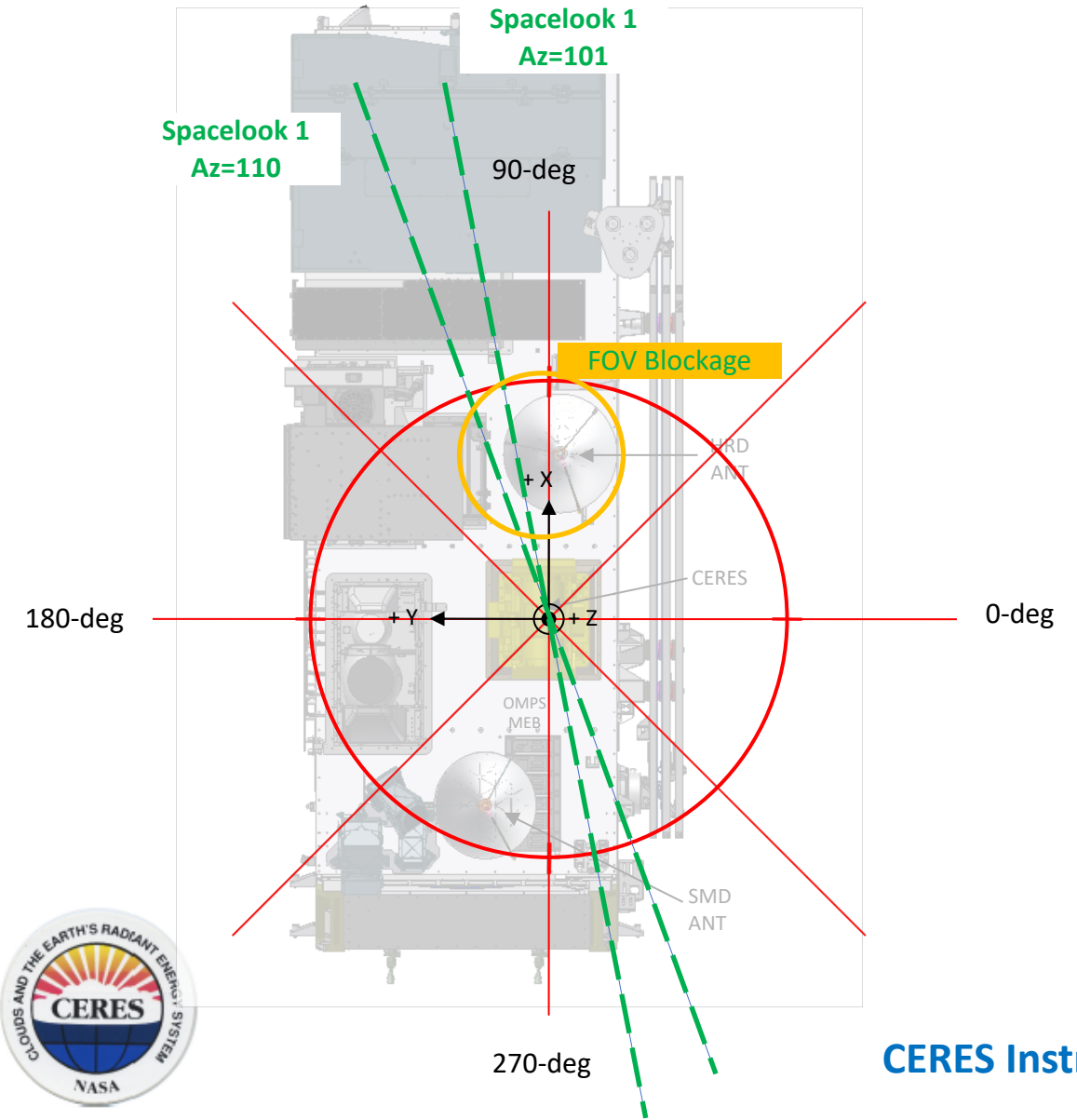
- **CERES FM6 instrument continues to show stable performance after the initial sensor response rise.**
  - ICM and solar calibration show good agreement.
  - Validations so far show no indication of spectral changes.
- **CERES FM5 Edition 2 has been validated and is ready for delivery. All validation studies show that Edition 2 corrects for the trends observed in Daytime LW in the Edition 1 validation studies.**
- **Terra and Aqua instruments' gains and SRFs for Edition 4 processing were delivered through June 2019. Validation results show consistent trends between all three instruments (FM1-FM3).**

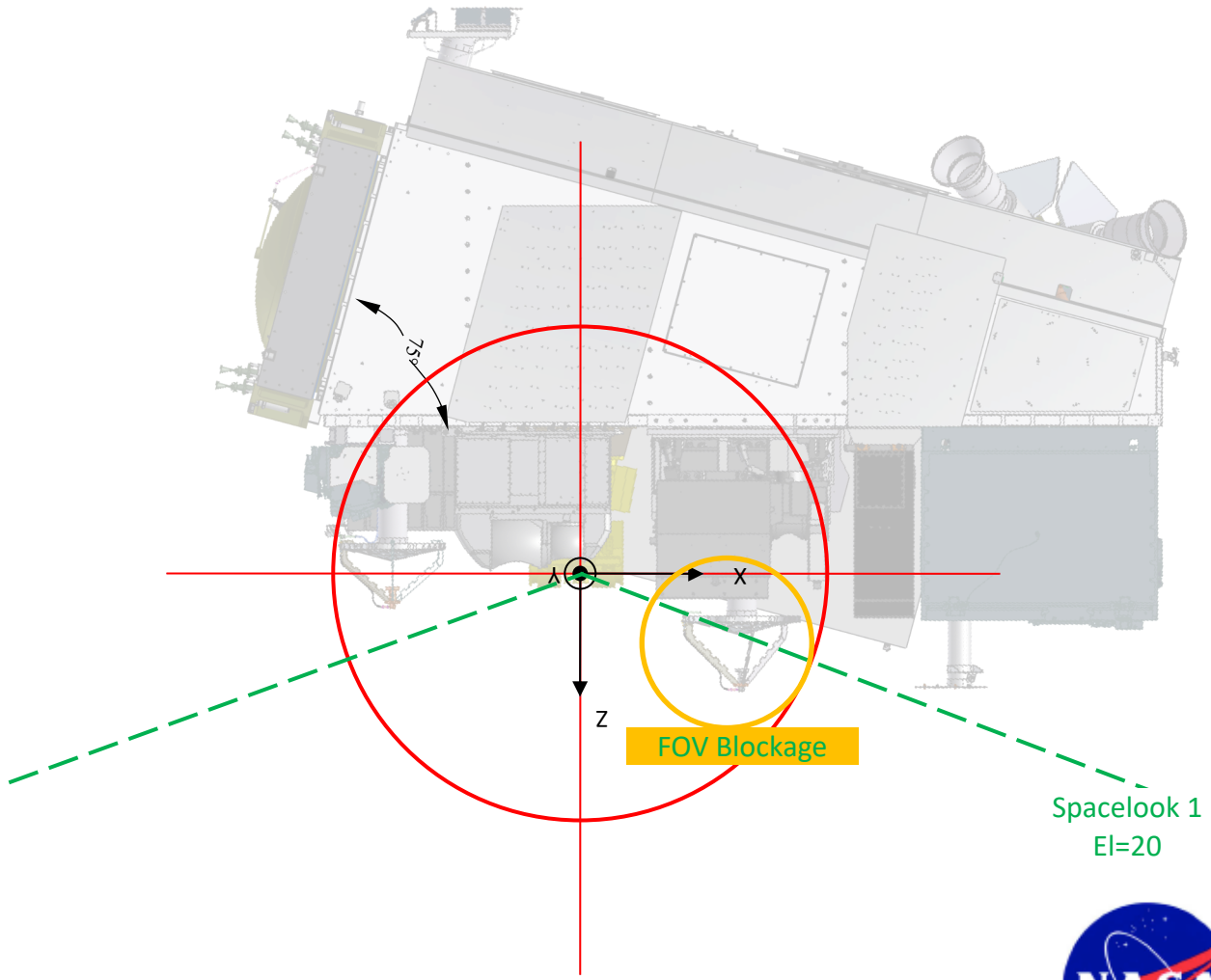
Backup


CLOUDS AND THE EARTH'S RADIANT ENERGY SYSTEM
CERES
NASA


NASA

S-NPP HRD Antenna and FOV blockage





CERES Instrument Working Group

NOAA-20/FM6 – Aqua/FM3 INTERCOMPARISON

Simultaneous Earth observation with Aqua/FM3

May – December 2018

ΔTime < 1min; ΔRAZ < 10°; ΔVZA <10°

All-sky

(FM6-FM3)/FM6	FM6 Radiance [W m^{-2} sr^{-1}]	Relative Error [%]	α-confidence [95%]	Number of samples
Shortwave	79 /88	**3.34 / 3.67**	.6 /.5	22/30
LW daytime	76 /76	**1.95 /1.18**	.2 /.1	23/31
LW nighttime	66 /68	**1.97/1.90**	.2 /.1	22/42

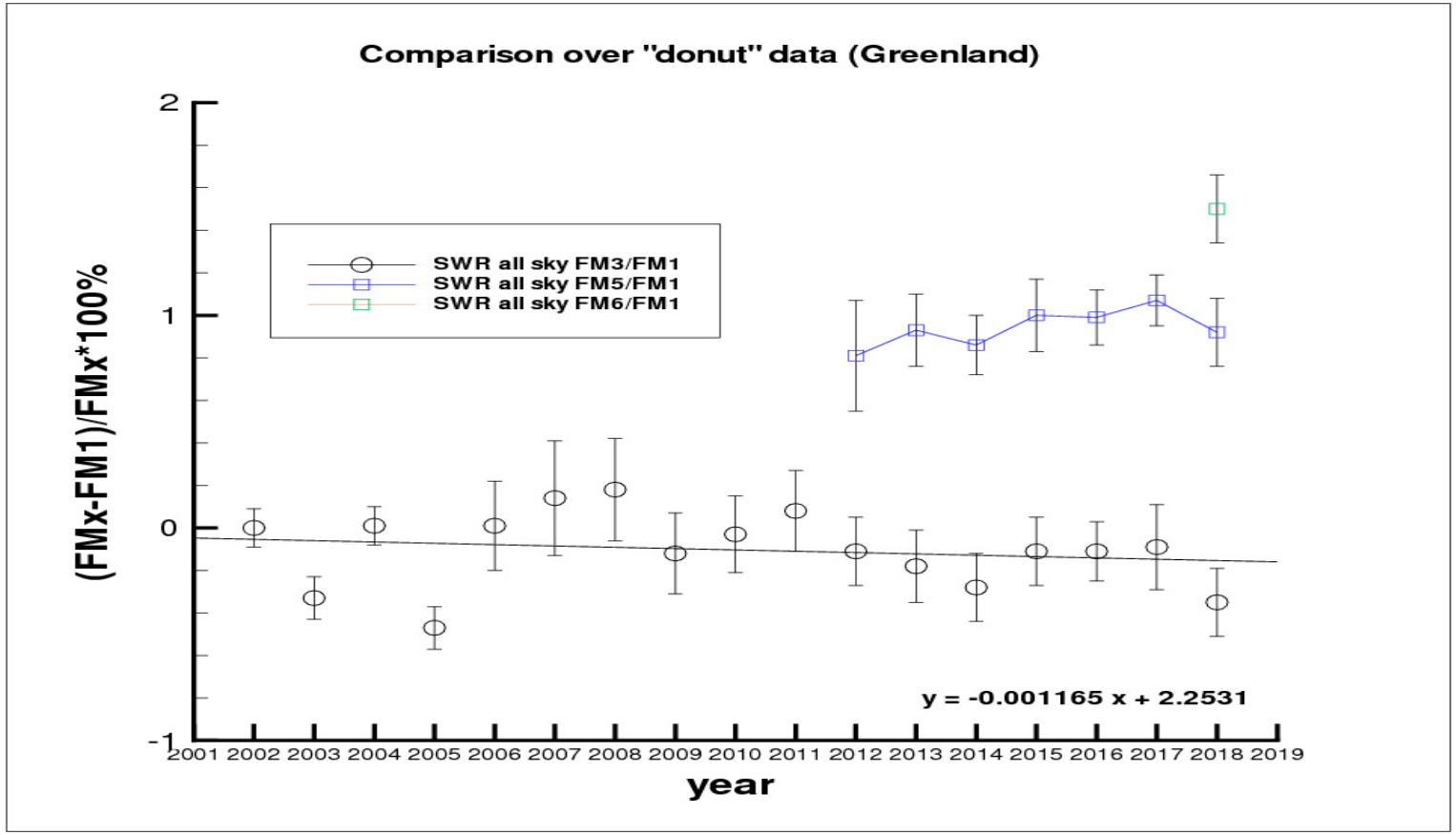
- Edition 1-CV for FM6 and Edition 4 for FM3 are used
- Shown differences are computed as “average of differences” to avoid error cancellation

Comparison of FM6/FM5/FM3 with FM1

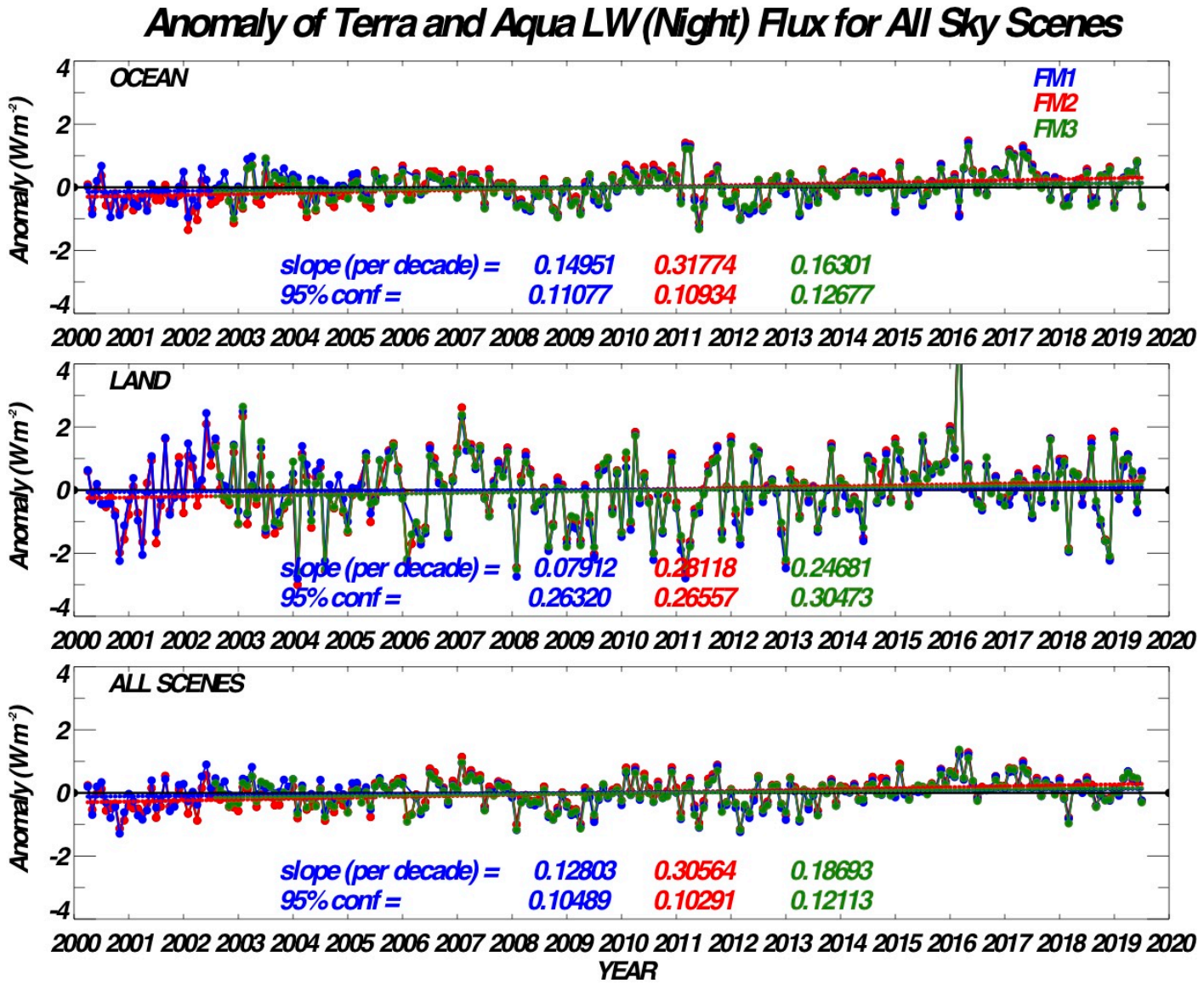
Minor Plane Scan(Greenland)

ΔRAZ < 10°; ΔVZA <10°

Edition 4 for FM3; Edition 1 for FM5; Edition 1-CV for FM6



Terra and Aqua Ed-4 Night Flux Anomalies



TERRA/AQUA/S-NPP Instrument Anomalies